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Early Evaluation of Controlled Crosses of Black Spruce (*Picea mariana* (Mill) B.S.P.)

by

Dianne J. Williams

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF Master of Science

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Date.....Apr 3/85.....

Abstract

Tree improvement programs for many of our North Temperate zone coniferous tree species are delayed by the length of time required by the progeny test. Growth regulation through the use of light, temperature, nutrients and growth hormones may not only accelerate identification of superior genotypes, but also facilitate the assessment of juvenile-mature correlations.

Sixteen controlled crosses of black spruce (*Picea mariana* (Mill) B.S.P.), outplanted by the Petawawa National Forestry Research Institute of Canada in 1973 and 1976 were made available for this study. Seed from the original crosses was utilized in a greenhouse experiment from which juvenile:mature correlations were prepared. Families represented 'fast' and 'slow' growers, as determined from field height measurements.

Results of the field test alone indicated highly significant family effect for height, diameter, and volume from four through ten years from outplanting. Moreover, 'slow' families ranked consistently at the bottom, and were statistically distinct from the 'fast' families. This enables family selection (for ten-year height) to be made as early as four years from outplanting.

Monthly measurements of morphological characters at ages three to six months in the greenhouse showed highly significant family variation for total height, root collar diameter, lateral branch number, needle number, volume,

branch length, total, shoot and root dry weights. Not only do these black spruce families exhibit significant variation, but as a result they should also respond to selection. Weekly application of $GA_{4/7}$ beginning at age 4.5 months influenced five- and six-month volume, six-month branch length, all dry weight measurements. Height growth was not significantly affected. Despite significant $GA_{4/7}$ treatment effect on the above measurements, the Familiy x Treatment interaction was only significant for six-month volume, lateral branch number, and the dry weight measurements.

Simple correlations and Spearman rank order correlations computed across the $GA_{4/7}$-treated and control, untreated seedlings indicated high, positive, statistically significant early growth measurements. Simple correlations between field and greenhouse means results indicated that height and dry weight measurements in the greenhouse were highly correlated with height at four to ten years in the field, as well as ten-year volume.

Differences in levels of endogenous GAs can be identified at the family level; this variation may be useful as a selection tool. In this study endogenous GA levels in four controlled crosses were predominantly not significantly correlated with field and early growth measurements, with the exception of three- and four-month height, five-month volume, and total and shoot dry weight measurements determined per plant. Trends of higher endogenous GAs in

'fast' growing families are suggested by the data; this hypothesis needs to be substantiated with additional GA bioassays.

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I would like to express my sincere appreciation to the members of my graduate committee for their assistance in this study. Many of the initial concepts and hypotheses for the study were the direct result of earlier work undertaken by Dr. Richard Pharis.

The provision of data and tree seed by the PNFRIC was essential to the study, as a result I am very thankful to Dr. K. Morgenstern and Dr. K. Yeatman for allowing me to use their materials in my own research.

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Table of Contents

Chapter — Page

I. Introduction 1

II. Materials and Methods 17

A. The Field Experiment 17

Experiment No. 358-C-1 20

Experiment No. 358-C-5-1 21

B. The Greenhouse Experiment 22

Establishment and Layout 22

Exogenous Application of Gibberellin $A_{4/7}$ ...26

Greenhouse Measurements 27

Seedling Harvest 30

Endogenous Analysis of Gibberellin-like Substances 31

C. Analyses of the Data 32

The Field Experiment 32

The Greenhouse Experiment 37

Combined Data 38

III. Results and Discussion 41

A. Field Experiments 41

358-C-1 41

358-C-5-1 55

B. Greenhouse Experiment 58

358-C-1 58

358-C-5-1 80

C. Combined Data 82

D. Analysis of Endogenous Gibberellin-like Substances 85

IV. Conclusions and Recommendations 102

References 109

V. Appendix I 121

List of Tables

Table	Description	Page
1	Summary of the black spruce controlled crosses provided by the PNFRIC	19
2	Seed weights of controlled crosses of black spruce	23
3	Family seed weight and germination records	25
4	Form of variance analysis for the field and greenhouse experiments	35
5	Form of variance analysis following application of $GA_{4/7}$ in the greenhouse	39
6	Percent field survival of nine black spruce crosses from Exp. No. 358-C-1 four- to ten-years from Outplanting	42
7	Bartlett-Box univariate homogeniety of variance test for black spruce controlled crosses	43
8	Spearman Rank Order correlation coefficients of nine families in field exp. 358-C-1	45
9	Simple (phenotypic) correlation coefficients for the nine families in field exp. 358-C-1	46
10	Phenotypic correlation coefficients of seven families (selves removed) in exp. no. 358-C-1	47
11	Mean squares for five age measurements on black spruce controlled crosses from PNFRIC exp. no. 358-C-1	50
12	Ranking and significance testing of nine black spruce controlled crosses from exp. no. 358-C-1 for height, diameter, and volume four through ten years from outplanting	52

13	Coefficients of Determination (r^2) from regressing total height of nine black spruce crosses on years from outplanting ..	54
14	Mean squares derived from the two-way ANOVA for two age measurements on black spruce controlled crosses from PNFRIC exp. 358-C-1	56
15	Ranking and significance testing of seven black spruce controlled crosses from exp. no. 358-C-5-1 for height five to seven years from outplanting	57
16	Mean squares from the two-way analysis of variance of three- and four-month greenhouse measurements in exp. 358-C-1	60
17	Mean squares derived from the three-way analysis of variance for five- and six-month greenhouse measurements	61
18	Spearman Rank Order correlation coefficients computed for treated black spruce seedlings grown for six-months in the greenhouse	64
19	Spearman Rank Order Correlation Coefficients for early growth measurements on untreated black spruce seedlings grown in the greenhouse	65
20	Relative ranking and significance of traits measured at ages three and four months in the greenhouse	67
21	Spearman Rank Order Correlation Coefficients for three and four month early growth measurements	69
22	Simple correlations for three and four Month Greenhouse Measurements	72
23	Ranking and significance testing of variables measured at five and six months in the greenhouse	73
24	Ranking and significance testing for five and six month measurements where the F x T interaction term was significant	74

25	Mean dry weight measurements of treated and untreated black spruce seedlings	77
26	Phenotypic correlation coefficients for early growth measurements on untreated black spruce seedlings grown in the greenhouse	78
27	Phenotypic correlation coefficients for early growth measurements on black spruce seedlings in the greenhouse	79
28	Simple correlations of means of field, greenhouse, and gibberellin measurements on black spruce	83
29	Spearman Rank Order Correlations for means of field, greenhouse, and gibberellin measurements on black spruce ..	84
30	Free gibberellin levels (ng) in black spruce (P. mariana) per plant	90
31	Free gibberellin levels (ng) in black spruce (P. mariana) per gram tissue dry weight	91
32	Free gibberellin levels (ng) in black spruce (P. mariana) per plant	92
33	Free gibberellin levels (ng) in black spruce (P. mariana) per gram tissue dry weight	93
34	Comparison of greenhouse height growth measurements of nine untreated black spruce families at ages three- to six-Months	97
35	Comparison of greenhouse height growth measurements of nine treated black spruce families at ages three- to six- months ...	98
36	Precursor levels (ng) in black spruce (P. mariana) per gram tissue dry weight ...	99
37	Precursor levels (ng) in black spruce (P. mariana) per plant	100

List of Figures

1 Controlled crosses in exp. 358-C-1 (x) and exp. 358-C-5-1 (o) 18

2 Example of the qualitative spectrum of P. mariana free acids 88

3 Example of the qualitative spectrum of P. mariana precursors 89

I. Introduction

The main concern of the tree breeder is to obtain maximum genetic gain in a specified period of time, and to achieve this requires effective planning (Faulkner,1967). Conventional tree improvement programs developed for North Temperate zone coniferous tree species have included the following elements:

1. Initial selections from the wild,
2. Matings of these selections,
3. Outplanting of the progeny,
4. Assessing the parents on the basis of the progenies' performance.

As the breeding value of a selected parent tree is assessed from the performance of its progeny (resulting from a particular mating system), the progeny test is an essential part of any tree breeding program (Faulker,1967; Webb,1963; Pollard and Logan,1976). However, it is also the most time consuming (Ledig,1974).

Forest geneticists need methods that accelerate identification of superior genotypes and juvenile-mature correlations (Wood and Hanover,1981), and to potentially increase genetic gains (Waxler and Van Buijtenen,1980). Thus, techniques for the early ranking, screening, or evaluation of the selected parents and progenies have been the focus of extensive research for several decades. Most of these efforts have been directed towards the identification of the "key" or most relevant parameters of seedling growth

that can be correlated with growth rates in maturing trees. (Pollard and Logan,1973,1979; Rediske,1974; Cannell *et al.*,1981). In effect, early selection in trees is indirect selection on the 'juvenile' trait, requiring a correlated response in the 'mature' trait (Lambeth, 1980).

In order to rank progenies for superior growth traits at an early age, it is essential to understand the process of growth in trees and the variables that control genotypic variation in growth. According to Ledig (1974), the first step in developing a procedure for early progeny evaluation is to construct a conceptual framework or model to explain this genetic variation in growth. A soundly-based breeding strategy for any species depends on reliable information on the underlying variation and pattern of inheritance of the character for which selection will be made (Samuel and Johnstone,1978; Sziklai,1974). Yet such information on the various growth characters is sparse, as is information about the specific traits or characters to measure.

Woody plants express both juvenile and mature stages of growth (Hackett,1976), although little is understood about the factors influencing the transition from the juvenile to mature state in most conifers (Cannell *et al.*,1981). There are no clear-cut distinctions between successive stages, although the adult condition is generally equated with the ability of the tree to flower (Hackett,1976). Consequently, not only is maturity in trees ill-defined, so is the length of time required to make reliable genetic evaluations from

selected materials in the field. Webb (1963), indicated that the length of time required to reach the height equivalent to two logs (32 feet) may be useful in the long-term evaluation of height and tree quality. The 'mature' tree needs to have attained a height which will represent a majority of its final volume; Johnson (1964) suggested that one-third of a rotation would be sufficient. Zobel and Kellison (1978) considered that many of the growth traits could only be evaluated from trees approaching half- to full-rotation age. In any case, older field experiments are considered to provide more reliable correlations (i.e., regarding their "predictive value") with juvenile seedling data. "The longer one waits and the closer the approach to harvest time, the more accurately can progenies with the greatest growth potential be recognized" (Rediske, 1974). Cannell (1978) suggested that judgement on family performance could not be made accurately until several years after trees have come into competition with each other.

Hackett (1976) noted that changes in the following morphological and physiological characters take place during tree growth:

1. Leaf shape and thickness
2. Season of leaf retention
3. Phyllotaxy
4. Thorniness
5. Pigmentation
6. Ability to form adventitious roots

Thus, use of the "concept of juvenility implies that there is a physiological state,the juvenile state, which manifests itself in various morphological and physiological phenomena observed in juvenile woody plants" (Borchert,1976). Borchert suggested that if such a discrete juvenile state existed, one should expect the manifestation of all juvenile characters to change at the same rate with increasing physiological age of the tree. Yet this is not the case (Webb,1963; Borchert,1976). The retention or loss of juvenile characters are often not highly correlated with each other, suggesting independent genetic control with respect to their quantitative expression and rate of change during maturation and aging. In addition, physiological aging proceeds at different rates in different shoots of a tree; most morphological and physiological changes are manifested in the youngest, most recently formed parts of the organism, whereas the older parts of the organism may retain both morphological and physiological characteristics of earlier developmental stages (Borchert,1976).

Changes in the extent of genetic variation of different characteristics may occur during the developmental stages of the life cycle (Sziklai,1974). Franklin (1979) illustrated that juvenile and mature phases of stand development for four conifers were quite different (even for the same trait). Genetic correlations were strongly positive and high within each phase, and weak or negative between phases. Namkoong *et al.* (1972) and Namkoong and Conkle (1976) showed

large changes in the relative magnitude of genetic and environmental effects on height growth during stand development. Consequently, Franklin (1979) recommended that selections should be deferred until one-half of the rotation age (under typical stand conditions), since there must be strong heritabilities and genetic correlations between juvenile and mature phases to reflect the effects of the same genes.

Although there are many examples of age-dependent variation in shoot growth (Borchert,1976), of particular interest is the ability of coniferous germinants and seedlings to maintain continuous, indeterminate, or "free" growth (Logan and Pollard,1976). In free growth, new stem units are initiated and extended without interruption on a continuously expanding stem; hence free growth is the only mode of growth from germination to budset in the first year.

In contrast to free growth is cyclic, predetermined, determinate, or "fixed" growth, the main mode of growth in mature conifers and in many juvenile conifers after the first "dormant" bud is set. In fixed growth new leaf and stem initials are assembled on a primordial shoot; these initials elongate and extend together after a period of dormancy (Pollard and Logan,1976) . Yet, juvenile and mature stages of tree shoot growth and development are also ill-defined.

Cannell *et al.* (1971) indicated that the heights of many *Pinus contorta* Dougl. provenances and open-pollinated

progenies have become closely correlated with differences in their seasonal duration of shoot apical meristematic activity. Yet, the difference in duration of shoot elongation after the first year of growth is often ignored as a selection tool, because shoots are then largely preformed and their elongation period is reportedly not then directly related to their period of apical meristematic activity. In fact, provenances or progeny of lodgepole pine with prolonged apical growth each autumn may generate more stem units in their buds, resulting in greater potential height growth. In addition, Pollard and Logan(1976) illustrated that free growth in ten provenances of black spruce (*Picea mariana* (Mill.) B.S.P.) can also be seen in subsequent years, augmenting the spring flush of determinate growth. Since these provenances of black spruce have different capabilities for free growth, the wide range of mean heights of various provenances can be attributed largely to variable amounts of free growth accumulating each year (Pollard and Logan, 1976). Thus the rank of any provenance at the seedling stage will reflect its capacity for free growth; seedlings not possessing free growth are at a disadvantage (Pollard and Logan,1976). Furthermore, Pollard and Logan (1979) suggested that provenance changes in rank in a field trial can, in part, be attributed to inherent differences in free growth in the juvenile stage. Not only can free growth in black spruce persist up to age 5-10 years, but since the two modes of growth may not be

highly correlated, it may take several decades for the effects of predetermined growth to manifest itself. Of the northern conifers, free growth has been reported in *Abies* and other *Picea* trees up to ten years of age (Nienstadt,1966; Jablanczy,1971).

These studies suggest that persistent free growth, in combination with fixed growth, could confound field results, consequently it may be advantageous to make family/provenance selections while the seedlings are all exhibiting free growth as their sole means of growth.

Hanover(1976,1980) indicated that in many "single-flush" North Temperate zone conifers, shoot elongation is typically completed rapidly (4-6 weeks in spruce and pine) during a period of favourable growth conditions . In addition, the seasonal duration of shoot elongation often varies with tree age (i.e., older trees cease shoot elongation earlier than seedlings) (Hanover, 1980; Kramer and Kozlowski, 1978). Thus, not only is there evidence of differences in type (i.e., fixed vs. free growth) of apical and lateral shoot growth in juvenile and mature phases, there also are marked differences in its duration (Young and Hanover, 1976).

Shoot extension in older (two or more years) seedlings for many determinate species of the Pinaceae is the result of growth from the previous year's primordia, is generally unaffected by photoperiod (during actual elongation), and depends on endogenous factors (Hanover, 1980). Conversely,

shoot growth extension in young seedlings (free growth) can result from primordia initiated during the current year and is sensitive to extended photoperiod. If long photoperiods are given to the developing seedling and other growth conditions are optimal, it will begin accelerated or free growth with epicotyl elongation and remain in the dynamic steady state of apical and lateral growth for months or perhaps years (Hanover *et al.*, 1976).

As the previous paragraphs suggest, these phases of annual growth are regulated both internally and externally. Internal regulation is the result of the actions and interactions of growth-promoting compounds and inhibitors; external regulation is acheived by the apical meristematic regions of the tree responding to environmental signals (Hanover,1980). Although the stem apical meristem functions as the control centre for growth and development (Hanover, 1980), new branches and vascular tissue arise specifically from the cortical meristem, stem elongation from the rib meristem, and stem lateral growth from the cells comprising the vascular cambium. Hanover(1980) suggested that meristems are regulated internally by growth regulators, enzymes, and metabolites, externally by light, water, temperature, gravity, minerals, gases, and microorganisms.

This would suggest that by manipulating these internal and external regulators, one could control growth and development of the tree or seedling. In fact, Hanover *et al.*(1976) indicated that determinate growth is not essential

to the tree in its early development, and that it is possible to control early growth so that it is indeterminate rather than determinate. Their program of early growth control is called Accelerated Optimal Growth (AOG). AOG is defined as the "programmed control of tree growth by the imposition of light and temperature regimes that prevent the onset of dormancy until a tree has reached the desired size" (Hanover,1976). However, it has generally not been possible to manipulate main stem elongation in most members of the Pinaceae once the seedling has been allowed to enter into a determinate annual growth cycle (Hanover,1980).

Hanover (1980) stated that the principal objectives of tree growth control are to either increase yield or quality traits of the tree directly, or to accelerate genetic improvement programs by shortening both generation intervals and time required for progeny evaluation. Improvement programs for forest tree species such as black spruce, that typically exhibit very slow juvenile growth rates, may be enhanced by growth control techniques (Hanover and Reicosky, 1972), if the juvenile:mature correlation still holds true under such AOG conditions

Hanover *et al.* (1976) indicated that the eight primary factors that control tree growth are:

1. Genotype or genetic makeup
2. Ontogenetic developmental stage or age
3. Light intensity, duration, and quality
4. Temperature of soil and air and cyclic variation

5. Water in soil and air
6. Mineral nutrient availability
7. Carbon dioxide concentration of air
8. Growth-regulating chemicals

The most critical factor in the AOG system is the manipulation of light duration, quality, and intensity. By increasing the daylength to one longer than that genotype is adapted, one can prolong the indeterminate vegetative growth stage. Better growth in high light intensities is a consequence of increased foliage production, which accompanied the increase in light (Logan, 1969). The minimum light intensity within a given photoperiod that is required to produce a seedling shoot length significantly greater than controls varies by species (Hanover,1977), and population within a species (Arnot,1979; Wheeler,1979). Light extension with natural daylight, low-intensity artifical light, and interruption of the dark period with low intensity light have all been successful in maintaining the indeterminate growth stage (Arnot,1979). Pollard and Logan(1976) indicated that to maintain free growth of coniferous seedlings in the absence of external stress, the maximum gain is achieved by extending the duration of growth rather than increasing the rate of daily growth. Although photoperiod (specifically daylength) may be thought of as a triggering mechanism for growth acceleration, it is insufficient alone for maintaining accelerated levels of seedling growth (Larson, 1974).

Hanover *et al.*(1976) recognized the potential for growth control through the use of growth regulators. Levels of endogenous growth regulators have been correlated with a number of growth and differentiation processes in forest trees; their exogenous application is known to positively affect these same processes (Ross *et al.*,1983; Pharis and Kuo,1977).

Of the regulators, gibberellins (GAs) are considered to play a rate-limiting and/or controlling role in shoot elongation in conifers (Pharis,1976). In particular, $GA_{4/7}$ is known to significantly enhance shoot elongation and volume growth in the Pinaceae (Pharis,1976), often at the expense of lateral shoot and root growth (Ross *et al.* 1983; Pharis and Kuo,1977).

Ross *et al.* (1983) suggested that a partial component of inherent vigor might consist of an enhanced ability to synthesize or maintain high levels of endogenous GAs, or to respond more effectively to a given level of the growth regulator. "Conversely, if endogenous levels of GA are truly a limiting factor in regulating final yield, then inherently 'fast-growing' trees might reflect this by responding less well to exogenous application of a GA".

This hypothesis suggests the possible use of hormone levels, balances or rates of metabolism for parental selection and progeny testing (Pharis,1976). It was speculated that the rate of metabolism of important growth hormones such as GAs could be correlated with inherent

differences in shoot elongation (Pharis,1976).

Preliminary studies by Pharis (Ross *et al.*1983) using *Pinus radiata* families indicated that early growth performance may be of predictive value for subsequent field performance. In addition, the potbound families' response to exogenous $GA_{4/7}$ provided insight into family ranking and performance. Thus Pharis(1976) foresaw the possibility of significant and rapid genetic gains through both parental selection and progeny testing by chemical and/or 'bioassay' methods. The 'bioassay' for inherent growth superiority in the field may be acheived through assessment of early growth performance under controlled environment conditions (Ross *et al.*,1983), or possibly by employing the AOG techiques developed by Hanover. "A means exists whereby free or accelerated growth can be maintained in juvenile trees during the very early stages of tree growth .... This technology could not only facilitate the evaluation of superior genotypes, but also the assessment of juvenile-mature correlations" (Wood and Hanover,1981; Hanover,1976).

Kang (1980) stated that AOG techniques were useful for traits with high heritabilities and positive juvenile-mature correlations. Wood and Hanover(1981) suggested that AOG conditions may reveal genetic differentiation patterns from provenance or progeny tests. Giertych (1974) suggested that progeny tests represented the greatest potential for successful early testing, since the study material is not

very diversified. Burdon (1982) stated that cultural environments could create a selective advantage for genotypes with greater growth potential; this could facilitate earlier expression of additive genetic variation in growth performance. Wheeler (1979) indicated that the possibility existed that selection for growth traits could be made at the provenance level at a relatively early age by employing growth accelation techniques, but that it would not be accurate enough for identification at the family or individual-within-family levels. In addition, Wheeler (1979) suggested that the relative ranking of lodgepole pine (*Pinus contorta* var. *latifolia* Dougl.) families, when grown under extended photoperiods, was not neccessarily indicative of performance of field-grown materials. Cannell (1978) stated that the light-saturated photosynthetic rates of young trees (i.e., as grown under the AOG regime) may not be indicative of their photosynthetic efficiency within the forest community. These arguments, if correct, would make the application of AOG techniques for early selection of superior progeny of questionable value.

One means of resolving this inconsistency between early or juvenile growth experiments and established (i.e., more than one-third of a rotation) field tests is to undertake both tests with identical genetic material. As Hanover and Reicosky (1972) commented, "only long-term observations and correlative analysis using plantation data will indicate the reliabilty and usefulness of such early observations in a

genetic improvement program". In addition, screening at an early age depends on juvenile performance being related to performance at maturity; provenance trials currently in progress could test that relationship (Logan, 1974).

Although provenance trial data could provide useful information for the calculation of correlations, progeny of a controlled cross should provide the most reliable data for the determination of inherent growth potential and/or ranking (R. P. Pharis, letter dated Mar. 8, 1983, to R. Burdon, For. Res. Inst., Rotorua, N. Z.). Not only are fewer seedlings required to achieve an acceptable level of statistical precision, but control-pollinated material can also be used to avoid potential problems in the interpretation of the data. Weak correlations with open-pollinated material are often attributed to the problem of large within-family variation.

Given that changes in rank, especially of the upper and middle performers, characterize many provenance and progeny tests to date, the forest geneticist may be more interested in identifying and rogueing the potential worst performers at a very early age. AOG techniques may enable the forest geneticist to quantitatively identify families that could be culled even before outplanting. In effect, early ranking techniques may be most valuable in determining the poorest performers, instead of the fastest growers.

Waxler and Van Buijtenen (1981) grew known fast and slow growing, open-pollinated loblolly pine families under

simulated field conditions and determined that seedlings grown under the unstressed regime yielded the best overall predictors of later field performance. 'Unstressed' conditions are provided under AOG conditions. Cannell (1981) indicated that differences in eight-year height growth of lodgepole pine was most successful when the trees were planted at sites favouring rapid growth. AOG conditions favour rapid growth. Lambeth (1979) also found that prediction of performance of twelve families on 'favourable' sites was as good or better than that on 'unfavourable' sites. Heritablity estimates also tended to be higher on favourable sites. In addition, seedling performance based on morphological traits would be valid only when seedlings were raised and tested in the same physiological condition (Richter, 1984).

Lambeth *et al.* (1982) also concluded that correlations between field and greenhouse environments were better than correlations with growth chamber environments, possibly due to effects of natural versus artifical lighting. Consequently, it may be most useful to conduct early evaluation experiments in a greenhouse environment, as opposed to a growth chamber.

Consequently, a starting point for this work may be to identify known 'fast' and 'slow' growing control-pollinated families from established field experiments on sites favouring rapid growth, and then to attempt to differentiate statistically between these two groups on the basis of their

juvenile performance in an optimal environment (AOG) test.

Thus, in this project controlled crosses of field-ranked black spruce have been used to achieve the following objectives:

1. To determine if early growth performance, assessed under near-optimal growing conditions, could be used as an early selection or screening technique.
2. To compare the performance of genetically identical greenhouse and field materials with juvenile-mature correlations for traits associated with tree growth and vigor.
3. To determine if exogenous application of the growth hormone $GA_{4/7}$ will influence the performance and/or rankings of the families.
4. To identify and quantify endogenous GA levels in families that consistently rank as 'fast' and 'slow' growers in both field and greenhouse environments, and to correlate these levels with inherent field growth and yield.

II. Materials and Methods

A. The Field Experiment

In the early 1970's Dr. E.K. Morgenstern of the Petawawa National Forestry Research Institute of Canada (PNFRIC) initiated two control-pollination experiments with black spruce (Viidak,unpl).

The origin of the parent trees was presumed to be local to the Petawawa, Ontario, area, and they were originally part of D. A. Fraser's physiology experimental area. The physiology experiment was situated close to the PNFRIC Headquarters, at an approximate Latitude of 45°58', Longtitude of 77°25', and elevation of 160m. The parent trees were planted in 1958; this work came to a close in 1970 (C. W. Yeatman, Pers. comm. September,1983).

For this study of early progeny evaluations the PNFRIC provided seed and field measurements of 16 selected controlled crosses from the two experiments described in the proceeding paragraphs. Several of the control-pollinated families are related (having a common parent), two are self-fertilized (selfed), and none are reciprocal crosses (Fig. 1). Thus, the experiments are made up of full-sibs, half-sibs, and selfed families. Each of the controlled crosses (now referred to as families) was classified as a 'fast' or 'slow' grower, based on 1981 total height growth at Petawawa. The PNFRIC provided field growth measurements up to December,1983 (Table 1).

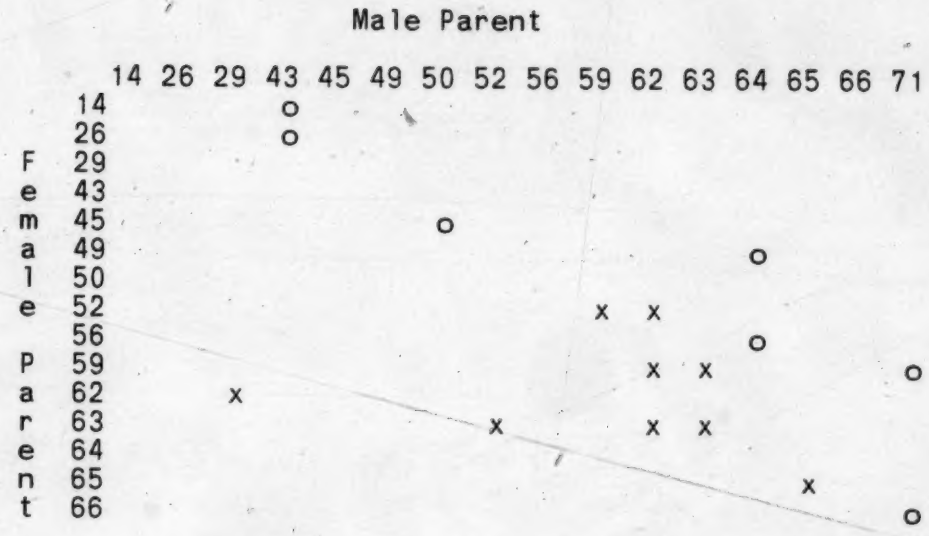

Fig. 1. Controlled crosses in Exp. 358-C-1 (x) and Exp. 358-C-5-1 (o).

Table 1. Summary of the black spruce controlled crosses provided by the PNFRIC

Exp. No.	Field Rating*	Family Number	Cross	Available Measurements 1977	1979	1981	1982	1983
358-C-1	Fast	7117	62x29	height	height	height	height	height & diameter
	"	7128	52x59	"	"	"	"	"
	"	7125	63x52	"	"	"	"	"
	"	7142	52x62	"	"	"	"	"
	"	7143	59x62	"	"	"	"	"
	"	7146	63x62	"	"	"	"	"
	"	7150	59x63	"	"	"	"	"
	Slow	7153	63x63	"	"	"	"	"
	"	7161	65x65	"	"	"	"	"
385-C-5-1	Slow	7513	14x43	---	---	height	---	height
	"	7537	45x50	---	---	"	---	"
	"	7545	49x64	---	---	"	---	"
	"	7549	56x64	---	---	"	---	"
	Fast	7518	26x43	---	---	"	---	"
	"	7551	59x71	---	---	"	---	"
	"	7553	66x71	---	---	"	---	"

*Based on 1981 total height growth.

⊕Numbers are those originally designated by PNFRIC.

Experiment No. 358-C-1

In 1970 E. K. Morgenstern utilized some of these black spruce parent trees in a control-pollination experiment of a 7x7 diallel design. Seeds from these crosses were sown in paper pots in a greenhouse in March, 1971. In July, 1971 seedlings were transferred to the nursery and transplanted into long frames. They remained there until the spring of 1973.

The planting site was a former hardwood stand which contained some spruces. From the access road, the site sloped uniformly to the east, where it was bordered by a black spruce muskeg. The soil was a fresh till with no boulder outcrops. Site preparation began in May, 1972, and included clearing of debris and spot marking of plant positions. Immediately prior to planting, scalping was done with Sandvick hoes.

All plants were lifted from nursery frames, placed on flats and transplanted to the site. Paper pots kept the original soil in place, and was thought to have had a marked effect on seedling recovery and subsequent growth (Viidak, unpl.).

Field planting took place on May 14-15,1973. Seedlings were outplanted in a Randomized Block Design with three replications,(3x3)=9 tree plots, at 6'x6' spacing. A total of 27 trees were planted of each seedlot. Two border rows surround the experiment.

Height measurements of the controlled crosses were taken in 1977,1979, 1981, and 1982 by the PNFRIC. Both height and diameter were measured in December, 1983, 13 years after seeding, or 10 years from outplanting. Diameter measurements were taken 50cm from the ground.

Experiment No. 358-C-5-1

In 1973 additional black spruce from the same physiology experimental area were used to test controlled crosses of design 1 and open-pollinated progenies (Viidak, unpl.).

Seedlots were again sown in paperpots, transferred to the nursery, and transplanted into long frames. The planting site was a former mixed hardwood site containing spruces, most of which were black spruce. The site slopes south, draining into a creek. Site preparations in May, 1976, included clearing of volunteer spruce and fir seedlings, as well as hand scalping. This was followed by field planting in a randomized block design with three replications and six tree plots. Thus a total of 18 trees of each controlled cross were planted.

Height measurements were taken in 1981 and December,1983 by the PNFRIC. The trees were considered to be too small for diameter measurements.

B. The Greenhouse Experiment

Establishment and Layout

Along with the field measurements described in the previous section, the PNFRIC provided approximately 100 seed of each of the 16 crosses. These 100 seeds per seedlot-family were weighed to the nearest .001g to determine the average seed weight per full-sib family (Table 2).

On April 20,1983, seed was cold-stratified on moist paper towels, according to methods described by the USDA (1974). Stratification generally reduces variation in germination rate among seedlots, which in turn tends to reduce differences in early seedling height (Wilcox, 1983; Sweet, unpl). In addition, seed weight and germination time tend to be largely independent of one another, at least in *P. radiata* D. Don (Sweet, unpl.).

On May 18, 1983, following 28 days of stratification, three seeds from each family were sown directly into four inch pots. Generally it is not only easier to regulate moisture levels with potted materials than with containerized seedlings, but also to limit pot-binding of the seedling root system. Since the seed was relatively old (from 1970 and 1972, respectively), three seeds were sown in each pot, with approximately 28 pots per family. Pots contained a 3:1 mixture of peat:vermiculite (Carlson,1983). Seeds were covered in sand, and a 4mm layer of plastic.

Table 2. Seed weights of controlled crosses of black spruce

Exp. No.	Family	Field* Rating	No. of Seed Weighed	Average Seed Weight Per Seed (grams)	Family Rank (based on seed weight)
358-C-1	7117	Fast	100	.00161	3
	7128	"	100	.00139	6
	7125	"	100	.00124	7
	7142	"	98	.00152	5
	7143	"	68	.00201	2
	7146	"	100	.00153	4
	7150	"	68	.00216	1
	7153	Slow	31	.00114	8
	7161	"	40	.00075	9
358-C-5-1	7513	Slow	100	.0016	1
	7537	"	100	.0011	5
	7545	"	100	.0016	1
	7549	"	100	.0014	3
	7518	Fast	100	.0015	2
	7551	"	100	.0011	5
	7553	"	100	.0012	4

*Based on 1981 total height growth.

Emergence was monitored on alternate days; each pot (within each family) was identified by date of emergence. First germinants were noted May 26, 1983; germination terminated June 11.

Based on the date of germination, three completely randomized blocks were established in the greenhouse. Block 1 was comprised of seedlings that had germinated by May 26; Block 2 May 28; Block 3 May 30 and June 1, 1983. Uneven germination restricted the number of individuals per family that could be included in a block or replicate (i.e., to maintain a balanced design). Germination varied from 27 to 75 percent (Table 3). Thus the randomized blocks were established with three replicates (blocks), 16 families, two treatments , three trees/family x block x treatment combination, for a total of 288 seedlings. This required 18 seedlings per family for the establishment of the experiment. Due to the germination of only 12 and 16 seedlings in the self-fertilized families (7153 and 7161), there were some missing trees from the onset of the experiment. Again, due to uneven germination, some transplanting was required. Logan(1973) indicated that white spruce (*Picea glauca* (Moench) Voss) seedlings could be transplanted between ages of three to 13 weeks with no appreciable affect on subsequent height growth. This was completed June 16,1983, and the blocks arranged on one greenhouse bench.

Table 3. Family seed weight and germination records

Exp. No.	Family	Seed Rank*	Total Number Planted	Number Germinated	Percent Germination
358-C-1	7143	2	68	27	40
	7117	3	100	48	48
	7150	1	68	28	41
	7146	4	100	75	75
	7142	5	98	45	46
	7128	6	100	27	27
	7125	7	100	51	51
	7153	8	31	12	39
	7161	9	40	16	40
358-C-5-1	7513	1	100	45	45
	7537	5	100	39	39
	7545	1	100	44	44
	7549	3	100	75	75
	7518	2	100	53	53
	7551	5	100	29	29
	7553	4	100	36	36

*Rank of family seed weight

Natural daylength exceeded 19 hours until mid July; supplemental lighting then was used to maintain the photoperiod at 16 hours. Mercury vapor lamps at approximately 1 metre above pot level provided light at 16μE/sec^{1}/m^{2}. Temperature was originally maintained at 20°C, but greenhouse problems allowed the temperature to fall and remain at approximately 10°C for as long as three weeks (during late July, early August). The entire experiment then had to be moved to another greenhouse; temperatures of 18°C were maintained for the remainder of the experiment.

Fertilization began June 21,1983, when the seedlings were approximately four weeks old. A spruce fertilizer of 112-55-156ppm N-P-K , plus 5.5ppm Fe (Carlson, 1983) was applied manually. Fertilizer was applied weekly thereafter, followed by a foliage rinse with a water spray.

Exogenous Application of Gibberellin $A_{4/7}$

Because the quantities of $GA_{4/7}$ that could be applied without phytotoxicity to black spruce seedlings were unknown, toxicity tests had to be undertaken. The growth hormone $GA_{4/7}$ was provided by R.P. Pharis[1]. On August 22, when seedlings were a minimum of 83 days from emergence, $GA_{4/7}$ was applied in two dosages to four seedlings/dose according to methodology described by Pharis (pers. comm., June 1983):

1. Store $GA_{4/7}$ at -20C. Warm to room temp before using.

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[1] Gibberellin $A_{4/7}$ ICI lot 24/365/CD 92.5% strength.

2. Sterilize beakers to avoid possible contamination.
3. Mix $GA_{4/7}$ with distilled water in two concentrations (100 ppm and 200 ppm).
4. Allow approximately one hour for hormone to dissolve. Maintain stirring and heat to maximum of 35°C.
5. pH will drop as hormone goes into solution; maintain at pH=8 with 3N potassium hydroxide.
6. Apply hormone as a root drench; approximately 50ml per pot to rooting zone.
7. Do not water for 12-24 hours following application of $GA_{4/7}$.
8. Wait 7-10 days for response (i.e. needle chlorosis,necrosis,wilting of new growth).

As a result of the toxicity tests, it was decided to apply $GA_{4/7}$ as a root drench in concentrations of 200 ppm to three seedlings per family x block combination. Initial growth measurements (August 6-7) indicated no differences ($P<0.05$) between seedlings designated for GA treatment or no treatment, thus original block structure was maintained. Exogenous $GA_{4/7}$ applications began September 2,1983 (age 12 weeks) and were continued weekly until October 28. The hormone was prepared weekly in the greenhouse and applied immediately.

Greenhouse Measurements

As previously stated, it was important to identify physiological characters that controlled genetic variation

in growth. In addition, these characters needed to be measured quickly and reliably on juvenile material (i.e., age three to six months from germination).

Herbert (1971), found that height, root collar diameter, number of lateral branches, and branch length provided a useful index of vigor in Sitka spruce (*Picea sitchensis* (Bong.) Carr); the number of fastigate branches and stem lean (i.e., deviations of the stem from vertical) played little part in the discrimination of progenies at one year of age. Conversly, Logan (1969) suggested that the accumulation of dry matter was a good index of growth. Both Lambeth(1980) and Waxler and Van Buijenten(1980) found the ratio of shoot/root dry weights and shoot dry weight alone to be the most highly correlated with field performance. Stem dry weight measurements provided a simple multiple of the weight of organic carbon metabolically assimilated as CO_2 (Ledig, 1974).

Although Ledig(1974) supported the utilization of photosynthetic CO_2 uptake in explaining growth, there are few examples of where it has proven to be a useful measure of vigor or growth potential (Hall and Miller, 1980). In addition, Logan(1971) recognized that photosynthetic rate per gram of leaf was not the sole determinant of growth in jack pine (*Pinus banksiana* Lamb.); there were crucial differences among provenances in other parameters of growth (such as leaf area development or duration of height growth). Thus it probably is not be possible to screen a

species by measuring photosyntetic rate alone. Pollard and Logan(1973) established that photosynthetic efficiency was not the most important parameter of growth for jack pine or white spruce *Picea glauca* (Moench) Voss.

Therefore, the following seedling growth variables were recorded monthly, from age three to six months in the greenhouse:

1. Height(cm) - measured with an ordinary ruler.
2. Root collar diameter(mm) - necessary in order to develop an index of stem volume.
3. Number of lateral branches (where elongation has taken place)- this also provides an indication of which families are putting photosynthate into the main bole, as opposed to branch development.
4. Branch length (longest lateral in mm).
5. Number of needles - as a measure of photosynthetic surface.
6. Number of dormant buds (including terminal) - important, as some bud set took place prior to final (6 mos.) measurements.
7. Dry weights - roots, needles (50 mature needles from base of main stem and lowest laterals), stem (needles removed),total (above-ground portion of stem).
8. Volume - cylinder (i.e., area of the base x height) (Husch *et al.*, 1972).
9. Rate of growth (increment) - computed between each measurement for each family (i.e.,

(height2-height1)/height1).

10. Change in growth (Δgrowth) between remeasurements.

Seedling Harvest

Following the final measurements, blocks were harvested for both dry weight measurements and endogenous hormone analysis. Consequently, dry weights were based on freeze-dried weights, as opposed to oven-dry weights. Methods followed those described by Pharis (pers. comm.):

1. - Wash roots.
2. - Cut seedlings at root collar.
3. - Quick-freeze in liquid nitrogen.
4. - Place roots and stem in labelled paper bags.
5. - Place bags in styrofoam cooler partially filled with liquid nitrogen.
6. - Cover cooler, transfer seedlings to deep freezer (-70°C).
7. - Pre-cool condenser of freeze-drier 20 min.
8. - Pre-cool trays with liquid nitrogen.
9. - Quickly transfer packaged seedlings to drier trays.
10. - Run drier at room temperature.
11. - Dry seedlings 3-5 days until brittle.
12. - Package dry seedlings in plastic bags. Add silica powder/dust to plastic bags.
13. - Heat seal bags; store at -20°C.

Endogenous Analysis of Gibberellin-like Substances

The consistent and highly correlated family performances in both field and greenhouse environments allowed for the selection of both fast and slow growers for the study of endogenous GA-like substances.

Based on five- and six-month total height and volume growth, a 'fast' and 'slow' growing/ranking family (in both field experiment 358-C-1 and its greenhouse test) was selected for the study of endogenous gibberellins. Additional families were later selected for subsequent hormone analysis that would allow for comparisons between families that shared common parents and consistent performance levels in both experiments. Fractions that would contain free GAs, GA precursors[2] and GA glucosyl conjugates were extracted and purified using preparative columns of C_{18} in combination with differential solvent solubility and short column procedure using SiO_2 partition column chromatography (Koshioka *et al.*, 1983).

GA precursors and free GAs underwent C_{18}HPLC for separation of components, followed by definitive bioassay for detection and quantitation (Koshioka *et al.*, 1983). The GA precursor fraction was run on a 60 to 90 percent HPLC gradient; the free GA fraction on a 32.5 - 73 percent HPLC. Levels of GA precursor-like and free GA-like substances were tabulated on a per gram dry weight and per plant basis, to

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[2] i.e., with C_{18} high performance liquid chromatography (C_{18}HPLC) retention times (Rts) similar to GA_{12}aldhyde, kaurenoic acid, and kaurene

determine if differences existed between 'fast' and 'slow' ranking families.

C. Analyses of the Data

The field and greenhouse experiments were initially studied separately in order to determine if significant differences existed among families for each trait. Families could then be ranked, and changes in ranking could be considered over time in both the field and greenhouse environments. These separate experiments could provide information on the consequences of making selections at different ages by considering the ranking of individual families at each assessment (Samuel and Johnstone, 1978). Rank order is of practical value in differentiating among families (i.e., for rogueing purposes) only if the family performance for any given trait is significantly different from another family (so that the slowest growers could be quantitatively distinguished from the faster growers). This would facilitate a potential rogueing program based on family ranking/performance.

Most of the data analyses were performed with the aid of SPSS^{x}(Statistical Package for the Social Sciences)(Anon, 1983).

The Field Experiment

The two field experiments were analyzed separately, due to differences in:

1. Numbers of individuals per family x replication established in each experiment,
2. the age of materials in each experiment, and
3. the number of repeated measurements available for each experiment.

An initial survey of the data included a summary of survival and descriptive statistics for each variable (trait) measured. Field survival and performance may be correlated, particularily in the case of the self-fertilized families. Analyses of variance were performed within each field experiment for the following traits:

1. Total height - measured repeatedly in each experiment,
2. Diameter - measured at year 10 for experiment 358-C-1,
3. Volume - computed for field experiment 358-C-1, based on ten year height and diameter measurements. (Volume was computed for each tree using dbh^2 x total height as an index of stem volume; Squillace and Gansel,1974).

The analysis of variance (ANOVA) was based on the following two-way linear model

$$Y = \mu + F_i + R_j + FR_{ij} + e_{(ij)k}$$

where,

μ is the experimental mean

F_i = effect of the family i, i=1,2,...a

R_j = effect of the replicate j, j=1,2,..b

FR_{ij} = the effect due to the interaction between the i family and the j replicate.

$e_{k(ij)}$ = the experimental error

Due to the varying number of trees per plot, the data set of experiment 358-C-1 was reduced from nine to seven trees per replicate; and experiment 358-C-5-1 from six to five trees per replicate. In order to create a balanced data set, three means had to be substituted for additional missing data in experiment 358-C-1. This method for handling missing data was selected (as opposed to those described by Becker (1975)), due to the problems of non-orthogonality imposed when a weighted or harmonic mean is used in ANOVA (Baker, pers. comm.[3]). Balancing of the data set also facilitated subsequent multiple comparison of family means.

The breakdown of the degrees of freedom, and expected mean squares are listed in Table 4. Due to lack of family structure it was impossible to consider trends in variances over time (Yeh, pers. comm.[4]). Not only were two of the families selfs (i.e., the inbreeding coefficient, F=.05), but the remainder of the crosses were either full- or half-sibs. In addition, the families selected represented only a subsample of the original experiment; any variance calculations derived from such a population would not reflect the effects of competition and/or spacing. Consequently, it would be difficult to interpret the value of the variance components.

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[3]Professor of Linguistics, Univ.of Alta., June, 1984
[4]Technical Advisor, Research Branch, Ministry of Forests, Victoria, B.C., July, 1984

Table 4. Form of variance analysis for the field and greenhouse experiments*.

Source of Variation	Degrees of Freedom	Estimated Mean Squares
Family(F)	f-1	$\sigma^2_e + n\sigma^2_{rf} + rn\sigma^2_f$
Replicate(R)	r-1	$\sigma^2_e + fn\sigma^2_r$
F x R	(f-1)(r-1)	$\sigma^2_e + n\sigma^2_{rf}$
Error	(n-1)fr	σ^2_e

*Three- and Four-month measurements only (i.e., prior to treatment application).

Since the differences among families were highly significant ($P<0.05$) for all three traits (height, diameter, volume), multiple comparisons of family means were tested with Duncan's Multiple Range test ($P<0.05$).

Homogeneity of within-family variances was computed with Bartlett's test (Zar, 1974). Spearman's rank order correlation coefficients were computed among families to evaluate the consistency of family performance throughout the duration of the field experiment. Additional coefficients were calculated in Exp. 358-C-1 among the seven non-selfed or 'fast' ranking families alone (in Exp. 358-C-1). Self-fertilization typically results in poorer growth performance in forest trees, and could confound the correlation coefficients, especially since only nine families had been used in their computation.

The correlation coefficient is a measure of the intensity of association between two variables (Zar,1974). Thus for each trait, the value in the last measure was correlated with that in each of the earlier measurements. Simple (phenotypic) correlations were computed within families and for all trees regardless of family. Within-family correlation relates to the early selection of individuals within families; total correlations should indicate the reliability of early mass selection (selection of individuals regardless of family) (Squillace and Gansel, 1974). To be most meaningful for tree breeding programs, these correlations should not only be statistically

significant, but also high (La Farge, 1975).

Height data followed a predominantly normal distribution within each family. Plots of residuals suggest a general linear relationship between family height and time; simple regression lines were calculated for each family using the model

$$Y = b_0 + b_1 t_j$$

where,

b_0 is the y intercept

b_1 is the slope

t_j corresponds to the j^{th} time

The Greenhouse Experiment

Analysis of the greenhouse data followed the same general procedures applied to the field experiment. Descriptive statistics were initially calculated for each variable. The identical two-way ANOVA model was used on the variables measured up to age four months; the growth hormone $GA_{4/7}$ was applied between the fourth and fifth monthly measurements. Therefore the fifth- and six-month measurements were analyzed with the following three-way ANOVA model:

$$Y = \mu + F_i + R_j + FR_{ij} + T_k + FT_{ik} + RT_{jk} + FRT_{ijk} + e_{(ijk)m}$$

where,

μ is the experimental mean

F_i = effect of the family i, i=1,2,...a

R_j = effect of the replicate j, j=1,2,...b

T_k = effect of the treatment k, k=1,...c

FR_{ij} = the effect due to the interaction between the i family and the j replicate.

FT_{ik} = the effect due to the interaction between the i family and the k time.

RT_{jk} = the effect due to the interaction between the j replicate and the k time.

FRT_{ijk} = the effect due to the three-way interaction between the i family, the j replicate, and the k time.

$e_{m(ijk)}$ = the experimental error

The breakdown of the degrees of freedom and estimated mean squares for the three-way model are presented in Table 5.

Significant differences ($P<0.05$) among families, in addition to their rankings, were identified with Duncan's Multiple Range test.

Spearman's Rank Order and simple correlation coefficients were computed across the entire data set (as they were in the field experiment), and for both $GA_{4/7}$-treated and control, untreated data sets. In this way treatment effect on family performance could be identified.

Combined Data

Family and replicate means were computed across both field and greenhouse experiments to create one data set.

Table 5. Form of variance analysis following application of $GA_{4/7}$ in the greenhouse.

Source of Variation	Degrees of Freedom	Estimated Mean Squares
Family	f-1	$\sigma^2_e + cno\,\sigma^2_{fr} + bcno\,\sigma^2_f$
Replicate	r-1	$\sigma^2_e + acno\,\sigma^2_r$
Treatment	t-1	$\sigma^2_e + ano\,\sigma^2_{rt} + abno\,\sigma^2_t$
F x R	(f-1)(r-1)	$\sigma^2_e + cno\,\sigma^2_{fr}$
F x T	(f-1)(t-1)	$\sigma^2_e + no\,\sigma^2_{frt} + bno\,\sigma^2_{ft}$
R x T	(r-1)(t-1)	$\sigma^2_e + ano\,\sigma^2_{rt}$
F x R x T	(f-1)(r-1)(t-1)	$\sigma^2_e + no\,\sigma^2_{frt}$
Error	(n-1)frt	σ^2_e

Although replicates were not identical in both experiments, they were maintained to provide more reliable or precise estimates of family means (Yeh, pers. comm.) In addition, since it was more important that the differences among families could be identified quantitatively, (i.e., that the families are significantly different from each other), the value of combining the data sets into one based on means is limited.

The separate greenhouse and field analyses (based on all observations, as opposed to means) quantitatively differentiated the families; means alone were used to determine the correlation of field and greenhouse performance, and the potential for predication of four- to ten-year field performance from three- to six-month greenhouse seedlings. As a result, only Spearman Rank Order correlation coefficients, and simple (phenotypic) correlations were calculated for the combined data set.

III. Results and Discussion

A. Field Experiments

358-C-1

Survival ranged from 74 to 100 percent after ten years in the field, with a self-pollinated family (7161) exhibiting the poorest field survival (Table 6). A ranking (based on percent survival at ten years after outplanting) for each family indicated that family 7143 trees were the highest ranking of the 'fast' growers, 7150 the poorest of this group, and 7161 the poorest of the 'slow' group. Percent survival, when combined with subsequent field performance records, may provide some indication of family field potential.

Descriptive statistics for each family and variable indicated high standard deviations for each variable, calculated either within- or among-families (Appendix I). Because control-pollinated material was used in this experiment, this suggests that environmental variation may have been largely responsible for the high standard deviations. This hypothesis is supported by the increasingly high within-family standard deviations for height over time. Bartlett's test of homogeneity indicates that within-family variances are not significantly different within the 'fast' growers alone, or within the entire group of families (Table 7).

Table 6. Percent field survival of nine black spruce crosses from Exp. No. 358-C-1 four-to ten-years from outplanting*

Family	Years from Outplanting				
	Four	Six	Eight	Nine	Ten
7143	100.0	100.0	100.0	100.0	100.0
7117	96.3	96.3	96.3	96.3	96.3
7150	92.6	85.2	85.2	85.2	85.2
7146	100.0	100.0	96.3	96.3	96.3
7142	92.6	92.6	88.9	88.9	88.9
7128	96.3	92.6	88.9	88.9	88.9
7125	96.3	92.6	88.9	88.9	88.9
7153	92.6	88.9	88.9	88.9	88.9
7161	85.2	77.8	74.1	74.1	74.1

*based on 27 trees per family

Table 7. Bartlett-Box univariate homogeniety of variance tests for black spruce controlled crosses

Experiment Number	Age of Height Measurement	Bartlett-Box F Statistic	Significance
35-C-1	four	1.07945	0.356
	six	0.97472	0.500
	eight	1.30623	0.136
	nine	1.34482	0.113
	ten	1.32674	0.123

Spearman's Rank Order correlation coefficients illustrate that height and volume rankings have been highly correlated throughout the duration of the field experiment (Table 8). These results are important, since the relative uniformity or consistency of family performance from four through ten years allows the use of only the oldest (i.e., ten-year) measurements in future comparisons with greenhouse results.

Phenotypic correlations for all trees regardless of family were positive and highly significant ($P<0.001$), suggesting the possibility for obtaining genetic gain in ten-year height with mass selection on four-year height (Table 9). Phenotypic correlations of ten-year diameter and volume were more highly correlated than height with volume; these results are consistent with those of Lambeth *et al.* (1983) for open-pollinated loblolly pine (*Pinus taeda* L.). Correlations computed across the seven 'fast' growers alone (i.e., selfs removed) are still positive and highly significant, although not as high as when the selfs were included (Table 10). Consequently, it is possible to continue to use all nine families in the preparation of correlation coefficients. Lambeth *et al.* (1983) and Lambeth (1980) supported selections (based on phenotypic correlations) as early as age six (with economic rotations of 30 years in loblolly pine). Family selections at age five were more accurate than individual tree selection. Squillace and Gansel (1974) reached similar conclusions with slash

Table 8. Spearman Rank Order Correlation Coefficients of nine black spruce families in field exp. 358-C-1.

	Four-Year Height	Six-Year Height	Eight-Year Height	Nine-Year Height	Ten-Year Height	Ten-Year Diameter
Six-Year Height	.938 N(189) SIG .000					
Eight-Year Height	.835 N(189) SIG .000	.902 N(189) SIG .000				
Nine-Year Height	.810 N(189) SIG .000	.885 N(189) SIG .000	.991 N(189) SIG .000			
Ten-Year Height	.803 N(189) SIG .000	.873 N(189) SIG .000	.971 N(189) SIG .000	.981 N(189) SIG .000		
Ten-Year Diameter	.763 N(189) SIG .000	.812 N(189) SIG .000	.904 N(189) SIG .000	.905 N(189) SIG .000	.891 N(189) SIG .000	
Ten-Year Volume	.789 N(189) SIG .000	.846 N(189) SIG .000	.943 N(189) SIG .000	.946 N(189) SIG .000	.941 N(189) SIG .000	.991 N(189) SIG .000

Table 9. Simple (phenotypic) correlation coefficients for the nine families in field exp. 358-C-1.

	Four Year Height	Six Year Height	Eight Year Height	Nine Year Height	Ten Year Height	Ten Year Diameter	Ten Year Volume
Four-Year Height	1.0000	.9376**	.8509**	.8303**	.8222**	.7841**	.7662**
Six-Year Height	.9376**	1.0000	.9192**	.9056**	.8970**	.8512**	.8339**
Eight-Year Height	.8509**	.9192**	1.0000	.9932**	.9777**	.9256**	.9094**
Nine-Year Height	.8303**	.9056**	.9932**	1.0000	.9877**	.9290**	.9043**
Ten-Year Height	.8222**	.8970**	.9777**	.9877**	1.0000	.9217**	.8922**
Ten-Year Diameter	.7841**	.8512**	.9256**	.9290**	.9217**	1.0000	.9481**
Ten-Year Volume	.7662**	.8339**	.9094**	.9043**	.8922**	.9481**	1.0000

*- significant at P<0.01 **- significant at P<0.001

Table 10. Phenotypic Correlation Coefficients of seven families (self's removed) in Exp. No.358-C-1.

	Variable						
	Four Year Height	Six Year Height	Eight Year Height	Nine Year Height	Ten Year Height	Ten Year Diameter	Ten Year Volume
Four-Year Height	1.0000	.8884**	.6951**	.6685**	.6346**	.5672**	.6096**
Six-Year Height	.8884**	1.0000	.7884**	.7746**	.7470**	.6507**	.6945**
Eight-Year Height	.6951**	.7884**	1.0000	.9889**	.9489**	.8206**	.8706**
Nine-Year Height	.6685**	.7746**	.9889**	1.0000	.9615**	.8177**	.8698**
Ten-Year Height	.6346**	.7470**	.9489**	.9615**	1.0000	.7895**	.8647**
Ten-Year Diameter	.5672**	.6507**	.8206**	.8177**	.7895**	1.0000	.9686**
Ten-Year Volume	.6096**	.6945**	.8706**	.8698**	.8647**	.9686**	1.0000

-* - significant at P<0.01 ** - significant at P<0.001

pine. Thus, earlier work with members of the Pinaceae support the trends illustrated by this study with black spruce.

Within-family phenotypic correlations were also positive and statistically significant for height ($P<0.001$), diameter and volume ($P<0.05$; Appendix I). Although the correlations are not as high or as uniformly significant as those favouring mass selection (as illustrated by total correlations), the results indicate the potential for early selection of individuals within families. Yet, because many within-family correlation coefficients decreased with age, it may be unwise to attempt within-family selection with material of ages four to ten.

Franklin (1979) stated that most genetic analyses of juvenile-mature relationships in growth traits such as height and volume have been based on estimates of phenotypic correlations of provenance or family means. Correlations have generally been high or at least positive, leading to the conclusion that selection based on juvenile traits is effective in obtaining genetic gain in mature traits (Squillace and Gansel, 1974).

Franklin (1979) suggested that phenotypic correlations alone ignore variation in the relative strength of environmental and genetic effects. Namkoong *et al.* (1972) and Namkoong and Conkle (1976) discussed large changes in the relative magnitude of genetic and environmental effects on height growth during stand development. They illustrated

that trends of correlations exist in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco); correlations are high and strongly positive within phases (i.e., 5-12 years, 18-23 years) and generally weak or negative between phases. Ross (pers. comm., August 1984, Victoria, B.C.) indicated that numerous problems existed within the data set used for Namkoong's study on Douglas-fir, and that the conclusions drawn from it may not be entirely reliable. Black spruce measurements from four to ten years from outplanting actually may correspond to 'within-phase' correlations. Moreover, these papers emphasized the importance of considering more than phenotypic correlations to develop reliable juvenile-mature correlations.

Two-way ANOVA of total height from four to ten years from outplanting indicated highly significant ($P < 0.001$) differences among families at each time of measurement (Table 11). Ten-year diameter and volume growth were also highly significant. Burdon (1982) suggested that despite low heritabilities for growth traits, coefficients of phenotypic variation are often large, especially for stem diameter. The existence of phenotypic variation in itself suggests the potential for genetic gain from selection (although it may not be a particularily efficient means of selection); good cultural environments may, in turn, lower phenotypic variation, but raise heritabilities and consequently improve gains (Burdon, 1982).

Table 11. Mean squares for five age measurements on nine black spruce controlled crosses from PNFRIC Exp. No. 358-C-1.

Source of Variation	Four-year Height	Six-year Height	Eight-year Height	Nine-year Height	Ten-year Height	Ten-year Diameter	Ten-year Volume
Family	15192.823 ***	40459.571 ***	89491.869 ***	125034.667 ***	167159.512 ***	31.416 ***	12629269.180 ***
Replicate	2020.228 ns	6398.778 *	12121.397 *	11599.397 *	14591.476 *	10.666 ***	4423908.538 ***
F x R	1449.013 *	3384.730 **	7899.022 ***	9461.075 ***	11091.476 ***	3.3012 ***	1278696.534 ***
Error	753.444	1530.071	2625.868	3252.041	3316.908	0.922	417924.782

ns = non-significant F test
* = significant at P<.05
** = significant at P<.01
*** = significant at P<.001

White spruce family height performance at both age 11 and 8 was highly correlated with age 22 height growth (Ying and Morgenstern, 1979), thus supporting the early identification and selection of superior progenies. Conversely, Wakely (1971) found that in southern pines phenotypic selection at ages lower than 20 years would increase the probability of overlooking ultimately superior families or trees within families. Thus, having established that the variables measured in the field portion of this black spruce study illustrated significant family differences, it is now important to differentiate among the black spruce families used in this study with a mean separation test.

Rankings of family mean heights, diameters, and volumes place family 7143 and 7150 consistently among the best performers for height growth, with 7146 intermediate, and the self-pollinated families (7153 and 7161) the poorest (Table 12). Statistical comparisons of family means indicate that most of the variation among families could be attributed to differences between the 'fast' vs 'slow' groups, as opposed to within-group variation. Although there were some changes in rank within the 'fast' group from four to ten years after outplanting, these changes were not significant, as illustrated by the Spearman Rank Order coefficients (Table 8).

Thus it is possible to statistically differentiate between the fast and slow groups; the groups remain

Table 12. Ranking and significance testing of nine black spruce controlled crosses from exp. no. 358-C-1 for height, diameter and volume four through ten years from outplanting

Family	Rank by Years from Outplanting						
	Four	Six	Eight	Nine	Ten[1]	Ten[2]	Ten[3]
	*a	a	a	a	ab	a	a
7143	1	1	2	2	3	6	6
	a	ab	a	a	b	a	a
7117	2	5	6	6	6	4	5
	ab	ab	a	a	a	a	a
7150	3	2	1	1	1	5	3
	ab	ab	a	a	ab	a	a
7146	4	4	5	5	5	7	7
	ab	ab	a	a	ab	a	a
7142	5	3	4	4	4	2	2
	ab	ab	a	a	ab	a	a
7128	6	6	3	3	2	1	1
	b	b	a	a	b	a	a
7125	7	7	7	7	7	3	4
	c	c	b	b	c	b	b
7153	8	8	8	8	8	8	8
	c	c	c	c	d	d	b
7161	9	9	9	9	9	9	9

[1] height [2] diameter [3] Volume

*similar letters in the indicate non-significant differences among families at P<.05 based on Duncan's Multiple Range Test

statistically distinct from four to ten years for all variables. Therefore, based on field performance alone, it is possible to eliminate the poorest growers at four years in the field. Yet because there are no 'slow growers' from a non-selfed cross included in this experiment, it cannot be stated conclusively that the slow growers would segregate from the fast growers in the field.

Although many families shared common parents it is difficult to establish any meaningful planned comparisons among the families, given that there is little within-group variation. Parent 63 served as either a male and female parent in families 7153, 7150, 7146, 7125. Families 7153 and 7125 are consistently among the poorest ranking families, yet 7146 and 7150 share not only a common parent with these poor performers, but also with the best performer (7143). This suggests that parent 59 and 62 may have potential as good general combiners.

Plots of family regression lines illustrated that height increment varied among families; the 'slow' growers (7153 and 7161), or selfs, were consistently increasing at a slower rate than the 'fast' growers. In addition, there were obvious differences among the 'fast' growers, eliminating the need to test the homogeneity of regression coefficients. Coefficients of determination (r^2) (Table 13) describe the amount of variability in height that can be accounted for by correlating height with years from outplanting. In all of the 'fast' growers, r^2 accounted for over 70 percent of the

Table 13. Coefficients of Determination (r^2) from regressing total height of nine black spruce crosses on years from outplanting

Family	r^2	
7143	0.779	
7117	0.742	
7150	0.847	*
7146	0.706	Fast Growers
7142	0.768	
7128	0.787	
7125	0.733	
7153	0.410	*
7161	0.605	Slow Growers

*based on eight-year height growth

variation; it explained only 41 to 60 percent of the variation in height growth in the 'slow' growers.

358-C-5-1

Not only were fewer families provided for this field experiment (seven as opposed to nine), but the field experiment was also younger, with only two height measurements available. For these reasons, this experiment was considered primarily to see if the results obtained in Exp. 358-C-1 could be reinforced with an additional group of seven families.

The two-way ANOVA (Table 14) indicates that family effect is also hightly significant; Duncan's Multiple Range test indicates that these differences can be attributed to between-group (i.e., 'fast' vs 'slow') as opposed to within-group differences (Table 15). The Spearman Rank Order and simple correlations are again high, positive, and statistically significant among and within the seven families. These results complement those in Exp. 358-C-1, although alone they are not as useful due to the limitations of the data in this second experiment.

Table 14. Mean squares derived from the two-way ANOVA for two age measurements on black spruce controlled drosses from PNFRIC exp. 358-C-5-1.

Source of Variation	Years From Outplanting	
	Five-Year Height	Seven-Year Height
Family	17065.952**	42783.730***
Replicate	960.238ns	9721.667ns
F x R	3160.238***	4522.778***
Error	1247.619	1873.810

** significant at P<0.05

*** significant at P<0.01

ns not significant

Table 15. Ranking and significance testing of seven black spruce controlled crosses from Exp. No. 358-C-5-1 for height five to seven years from outplanting.

Family	Rank by Years from Outplanting	
	Five	Seven
	*	
	a	a
7553	1	1
	a	a
7518	2	3
	a	a
7551	3	2
	b	b
7513	4	4
	b	b
7545	5	5
	b	c
7549	6	7
	b	bc
7537	7	6

*similar letters in a column indicate non-significant differences among families at $P<.05$.

B. Greenhouse Experiment

358-C-1

Germination ranged from 27 to 75 percent in experiment 358-C-1 families; 29 to 75 in experiment 358-C-5-1 (Table 3). Although in experiment 358-C-1 family 7128 (a 'fast-grower') had the poorest germination; the 'fast-growers' generally had a greater percent germination. This represented an average of 46.8 percent for the 'fast' group and 39.5 percent for the 'slow' group. Differences between the groups (as indicated by "t" statistics) are not significant ($P<0.05$). In addition, the fast growers had the largest seed, and the selfs the smallest. These differences were also not significant. Dunlap and Barnett (1983) suggested that speed of germination made a substantial contribution to early size differences among seedlings of loblolly pine. In their experiments the initial advantage of large seed size and rapid germination was maintained throughout early seedling development, although Dunlap and Barnett (1983) indicated that germination rates and subsequent early growth can be manipulated in pines through sizing and stratification. As a result, to minimize these effects, black spruce seed was stratified and blocks established on the basis of the date of germination, although it was later determined that the selfed seed was not significantly smaller than the open-pollinated seed, nor did the smaller selfed seed germinate at a significantly

slower rate.

Descriptive statistics for each family and variable (Appendix I) illustrate that only for needle number at four-months is the standard deviation high. This variable became too difficult to assess beyond four-months, and consequently was no longer recorded.

Results of two-way ANOVA (Table 16) on variables measured prior to treatment (i.e., at three and four months) indicate the family effect was highly significant ($P<0.001$).

The three-way ANOVA (Table 17) determined significance of family and treatment for variables measured at five and six months (i.e., following treatment application). Family effect was highly significant ($P<0.001$) for all variables except the number of dormant lateral buds. There were no differences among families in the number of dormant buds or in the rate of growth at six months. This is important, since differences in the number of dormant buds may have confounded many of the final (six month) measurements of height and dry weight. The fact that the parent trees used in the crosses were all local to the Petawawa area, as well as the use of extended photoperiods and weekly fertilization (part of the AOG regime) probably limited the significance of dormant bud formation. Since this was a greenhouse experiment (i.e., natural light was used primarily) dormant buds may have formed much earlier than if growth regulation was not utilized. However, Hanover (1976) tabulated the physiological and morphological response of tree seedlings

Table 16. Mean squares from the two-way analysis of variance of three- and four-month greenhouse measurements in Exp. 358-C-1.#

Source of Variation	Variable					
	Three-Months			Four-Months		
	Height	Lateral Branch Number	Needle Number	Height	Lateral Branch Number	Needle Number
Family	*** 11.125	*** 21.661	*** 1327.275	*** 21.243	*** 49.842	*** 5356.615
Replicate	*** 7.871	ns 1.173	ns 177.884	* 5.580	* 14.653	ns 592.440
F x R	ns 0.597	ns 1.701	ns 73.267	ns 0.949	ns 3.704	ns 242.708
Error	0.635	1.215	63.130	1.416	4.175	308.324

ns = not significant
* = significant at P<.05
** = " " P<.01
*** = " " P<.001
# = entire dataset used

Table 17. Mean squares derived from the three-way analysis of variance for five- and six-month greenhouse measurements

Source of Variation	Variable												
	Five Months				Six Months						Dry Weights		
	Height	Volume	Lateral Branch Number	Diameter	Height	Volume	Lateral Branch Number	Diameter	Branch Length	Dormant Bud Number	Total	Shoot	Root
Family	*** 42.163	*** 0.060	*** 137.518	*** 0.005	*** 72.336	*** 0.299	*** 250.107	*** 0.012	*** 86.341	ns 55.863	*** 0.817	*** 0.067	*** 0.023
Replicate	ns 7.849	** 0.032	*** 192.773	*** 0.005	ns 6.547	ns 0.750	*** 205.636	* 0.004	* 22.121	ns 67.002	*** 1.160	*** 0.059	*** 0.033
Treatment	ns 30.074	ns 0.022	** 271.367	** 0.004	ns 0.490	*** 0.893	*** 2527.024	ns 0.030	* 57.253	*** 2053.292	*** 0.582	* 0.027	*** 0.124
F x R	ns 4.710	ns 0.007	ns 13.857	ns 0.001	ns 12.278	ns 0.037	ns 20.343	ns 0.001	ns 10.909	ns 25.460	ns 0.072	ns 0.006	ns 0.003
F x T	ns 6.361	ns 0.006	ns 21.344	ns 0.000	ns 12.462	** 0.057	** 61.135	ns 0.002	ns 5.996	ns 12.333	* 0.118	* 0.009	** 0.004
R x T	ns 3.981	ns 0.002	ns 21.664	ns 0.000	ns 12.914	ns 0.001	ns 28.440	ns 0.000	ns 2.980	ns 55.979	ns 0.004	ns 0.002	ns 0.003
F x T x R	* 8.557	ns 0.006	ns 14.912	ns 0.001	ns 12.605	ns 0.013	ns 14.509	ns 0.001	ns 6.617	* 51.002	ns 0.035	ns 0.003	ns 0.000
Error	4.480	0.006	12.258	0.001	13.061	0.028	17.885	0.001	6.494	25.805	0.051	0.005	0.009

ns = not significant
* = significant at P<.05
** = significant at P<.01
***= significant at P<.001

to accelerated growth conditions; weak bud formation followed by subsequent growth can occur even under an AOG regime. Black spruce may respond to AOG in such a way, although the long periods of low temperatures experienced in this project suggest otherwise.

Treatment effect after $GA_{4/7}$ application was significant for nine of the thirteen variables recorded. Although it did not significantly affect height growth or six-month diameter growth, dry weights, the number of lateral branches and branch length were variables that were strongly affected by exogenous GA application. The $GA_{4/7}$-treated seedlings had fewer lateral branches at five and six months, shorter branch lengths, lower root, shoot, and total dry weights, smaller diameters at five months, yet had more dormant buds than the control, untreated seedlings. Ross *et al.*, (1983) indicated that "enhanced height growth in conifer seedlings from GA applications usually is at the expense of lateral branches and often also root growth". Although $GA_{4/7}$ application did not significantly affect seedling height growth, it did reduce branch numbers and dry weights. In addition, these effects may have a negative influence on seedling survival.

As indicated in the above paragraph, height at five- and six-months was not significantly affected by $GA_{4/7}$ treatment. Consequently, the change in height (Δheight) was considered from four- through to six-months, but it indicated no significant differences among the nine families

for Δheight6-5months, or Δheight5-4months, regardless of treatment. Δheight from four- to six-months indicated no significant differences between the $GA_{4/7}$-treated families, and only minor differences between the control, untreated selfs and the fast-growers. However, it is interesting that Δheight values for treated and control, untreated seedlings indicate that the $GA_{4/7}$ treatment is most strongly affecting the lower-ranking families, including the selfs.

Despite the uniformly high family, and to a lesser degree treatment effect, the family x treatment (FxT) interaction term was only significant ($P<0.05$) for five of the thirteen variables. Significant variables included six-month measurements of the number of lateral branches, volume, and dry weights. With the exception of these variables the nine families remained in the same relative rank order despite $GA_{4/7}$ application. Spearman Rank Order correlation coefficients of treated and control, untreated seedlings (Tables 18 and 19) confirm that family rank remained uniform for the variables recorded from three to six months.

All of the variables measured in the greenhouse could be used to differentiate among families; the nature of these differences (i.e., within groups or among groups) is of primary importance if field performance and, ultimately, rogueing is to be determined from greenhouse results. Thus, it was important to statistically separate family means with Duncan's Multiple Range Test. Variables measured prior to

Table 18. Spearman rank order correlation coefficients computed for treated black spruce seedlings grown for six months in the greenhouse

	HT1	HT2	HT3	HT4	VOL3	VOL4	D3	D4	L1	L2	L3	L4	N1	N2	DM4	BL4	TDW	SDW	NDW	RDW
HT2	.795**																			
HT3	.453**	.600**																		
HT4	.263	.448**	.609**																	
VOL3	.347*	.470**	.720**	.387**																
VOL4	.278*	.365*	.509**	.686**	.615**															
D3	.289*	.374*	.447**	.228	.919**	.535**														
D4	.258	.283*	.353*	.353*	.582**	.913**	.576**													
L1	.566**	.435**	.468**	.338*	.448**	.481**	.382**	.454**												
L2	.485**	.531**	.421**	.400**	.499**	.477**	.414**	.430**	.657**											
L3	.378**	.424**	.511**	.348*	.664*	.448**	.606**	.386**	.494**	.554**										
L4	.247	.330*	.439**	.392**	.543**	.526**	.506**	.504**	.454**	.728**	.667**									
N1	.858**	.726**	.477**	.284*	.441**	.438**	.364*	.421**	.607**	.620**	.414**	.383**								
N2	.636**	.773**	.508**	.494**	.444**	.517**	.361*	.412**	.502**	.560**	.443**	.466**	.722**							
DM4	.266	.187	.381*	.562**	.332	.468**	.175	.346*	.430*	.311*	.214	.183	.302*	.284*						
BL4	.284*	.458**	.459**	.522**	.501**	.581**	.471**	.508**	.499**	.506**	.466**	.573**	.321*	.400**	.222					
TDW	.265	.447**	.548**	.485**	.710**	.681**	.663**	.657**	.541**	.596**	.583**	.704**	.423**	.410**	.165	.754**				
SDW	.302*	.516**	.629**	.606**	.757**	.762**	.685**	.684**	.563**	.604**	.634**	.686**	.454**	.490**	.269	.762**	.959**			
NDW	.007	.034	.078	.022	.347*	.326*	.382**	.471**	.178	.183	.185	.284*	.063	.106	.158	.261	.457**	.346*		
RDW	.240	.364*	.512**	.444**	.695**	.728**	.611**	.742**	.543**	.485**	.499**	.567**	.373*	.339*	.284*	.552**	.763**	.772**	.398*	
WT	.372*	.384*	.187	.224	.255	.347**	.287*	.318*	.418**	.487**	.384**	.452**	.465**	.504**	.074	.474**	.416**	.406**	.007	.310*

HT1=3-Month Height
L1 =3-Month Number of Lateral Branches
N1 =3-Month Number of Needles
HT2=4-Month Height
L2 =4-Month Number of Lateral Branches
N2 =4-Month Number of Needles
HT3=5-Month Height
D3 =5-Month Diameter
L3 =5-Month Number of Lateral Branches
HT4=6-Month Height
D4 =6-Month Diameter
L4 =6-Month Number of Lateral Branches
DM4=6-Month Number of Buds
BL4=6-Month Length of Longest Lateral
TDW=6-Month Total Above-Ground Dry Weight
NDW=6-Month Needle Dry Weight
SDW=6-Month Stem and Branch Dry Weight
RDW=6-Month Rot Dry Weight
VOL3=5-Month Volume
VOL4=6-Month Volume
WT =family seed weight

Table 19. Spearman Rank Order Correlation Coefficients for early growth measurements on untreated black spruce grown in the greenhouse

HT2	.881**																		
HT3	.870**	.734**																	
HT4	.876**	.801**	.837**																
VOL3	.864**	.718**	.771**	.736**															
VOL4	.868**	.741**	.691**	.704**	.807**														
D3	.541**	.579**	.519**	.562**	.910**	.737**													
D4	.837**	.585**	.518**	.476**	.708**	.943**	.695**												
L1	.675**	.660**	.518**	.520**	.687**	.662**	.627**	.618**											
L2	.581**	.620**	.302*	.428**	.612**	.6200**	.655**	.647**	.744**										
L3	.344*	.410**	.365*	.359*	.646*	.587**	.686**	.668**	.606**	.733**									
L4	.369**	.500**	.407**	.431**	.579**	.646**	.585**	.697**	.601**	.717**	.812**								
N1	.869**	.832**	.623**	.648**	.728**	.725**	.627**	.645**	.805**	.698**	.493**	.525**							
N2	.735**	.834**	.640**	.646**	.748**	.735**	.667**	.673**	.747**	.711**	.538**	.602**	.868**						
DM4	.229	.165	.107	.232	.084	.093	.014	.010	.128	.132	-.196	-.241	.270*	.188					
BL4	.673**	.688**	.579**	.613**	.643**	.689**	.605**	.617**	.635**	.576**	.494**	.503**	.693**	.658**	.043				
TDW	.547**	.632**	.541**	.570**	.743**	.781**	.737**	.780**	.692**	.754**	.766**	.788**	.677**	.701**	-.078	.796**			
SDW	.680**	.755**	.650**	.697**	.813**	.874**	.773**	.814**	.720**	.710**	.680**	.710**	.751**	.755**	.020	.830**	.947**		
NDW	.123	.128	.160	.204	.282*	.309*	.322*	.332*	.156	.227	.323*	.256	.140	.072	.016	.262	.472**	.433**	
RDW	.406**	.517**	.452**	.458**	.622**	.734**	.624**	.782**	.574**	.628**	.651**	.593**	.586**	.614**	-.029	.692**	.832**	.789**	.362*
WT	.525**	.526**	.481**	.400**	.515**	.561**	.445**	.566**	.583**	.448**	.504**	.514**	.582**	.668**	-.037	.479**	.510**	.533**	.006	.517**
	HT1	HT2	HT3	HT4	VOL3	VOL4	D3	D4	L1	L2	L3	L4	N1	N2	DM4	BL4	TDW	SDW	NDW	RDW

treatment (i.e., three- and four-month) were considered first, followed by the treated and control, untreated five- and six-month variables.

Rankings of families for variables measured prior to treatment (Table 20) illustrated that family 7143 was consistently first or second in three- and four- month height, the number of lateral branches and needles (at three and four months). In fact, the 'fast' growers were consistently in the highest ranking positions; the selfed, poor growers in the lowest positions. The only exception was the number of laterals at three months; family 7125 (generally the poorest of the 'fast' group) was ranked below 7153, one of the 'poor' growers.

At $P<0.05$ it was possible to differentiate between the 'fast' and 'slow' groups based on three- and four-month growth, although the value of this is limited due to the fact that the only statistically significant 'slow' growers are selfs. Only family 7125 (consistently the lowest ranking of the 'fast' group) could not always be separated from the 'slow' group (based on the number of lateral branches or needles at three- and four-months). The 'fast' group exhibited significant within group variation for all variables but four-month lateral branch number. The slow growers were not significantly different from each other for any variables. Because family 7125 could not be separated from the slow growers for the number of lateral branches and needles (at $P<0.05$), those variables may not be useful for

Table 20. Relative rankings and significance of traits measured at ages three and four months in the greenhouse

Family	Variable					
	Three-Months			Four-Months		
	Height	Lateral Branch Number	Needle Number	Height	Lateral Branch Number	Needle Number
	#					
7143	a 1	a 1	a 2	a 1	a 2	a 1
7117	ab 2	ab 2	a 1	abc 3	a 1	ab 2
7128	abc 4	c 5	b 5	abc 4	a 4	b 6
7142	ab 3	bc 3	b 3	ab 2	a 5	b 4
7150	cd 6	c 6	b 6	bcd 5	a 3	b 3
7146	bcd 5	bc 4	b 4	cd 6	a 6	b 5
7125	d 7	d 8	c 7	d 7	bc 7	c 7
7153	e 9	d 9	cd 8	e 8	c 9	cd 8
7161	e 8	d 7	d 9	e 9	c 8	d 9

#Families with common letters are not significantly different ($P<.05$).

early selection or differentiation of fast and slow groups. However, since 7125 was always significantly different from the remainder of the 'fast' growers, use of those variables for early selection could possibly mean elimination of only one of the fast growers. At this time it is unknown exactly what position family 7125 occupied in the entire field experiment; only field performance information for these nine families was made available for this study. Without this information, it is impossible to really consider the implication of the selection or elimination of the slowest growers based on the three- and four-month number of needles or branches.

Thus, the 'fast' growers (except 7125) were essentially taller, faster growing, possessed more lateral branches and needles (hence a larger photosynthetic surface) and were consistently more vigorous than the 'slow' growers at three and four months. Herbert (1971) found strong positive correlations among height, branch number, and branch length in an open-pollinated Sitka spruce *Picea sitchensis* (Bong.) Carr. glasshouse study. Faulkner (1967) found that one-year control-pollinated Sitka spruce grown under glasshouse conditions showed considerable within-progeny group variation for height, root collar diameter, branch numbers and lengths, angle of branching, stem leans and stem bends.

Across family Spearman Rank Order correlation coefficients were all positive and highly significant ($P<0.001$, table 21). Thus, family rank was statistically

Table 21. Spearman Rank Order Correlation Coefficients for three- and four-month early growth measurements of black spruce.*

	Three Month Height	Four Month Height	Three Month Laterals	Four Month Laterals	Three Month Needles	Four Month Needles
Four Month Height	.825 N(148) SIG .000					
Three Month Laterals	.623 N(148) SIG .000	.548 N(148) SIG .000				
Four Month Laterals	.536 N(148) SIG .000	.571 N(148) SIG .000	.704 N(148) SIG .000			
Three Month Needles	.859 N(148) SIG .000	.776 N(148) SIG .000	.718 N(148) SIG .000	.672 N(148) SIG .000		
Four Month Needles	.687 N(148) SIG .000	.802 N(148) SIG .000	.627 N(148) SIG .000	.646 N(148) SIG .000	.797 N(148) SIG .000	
Family Seed Weight	.429 N(148) SIG .000	.437 N(148) SIG .000	.507 N(148) SIG .000	.466 N(148) SIG .000	.526 N(148) SIG .000	.600 N(148) SIG .000

*Measurements recorded on all seedlings prior to treatment.

uniform for the variables measured up to and including four-month growth.

Seed weight was included in Tables 18 and 19 of rank order correlations; it was also positively and significantly correlated with each variable measured prior to treatment application, and had the potential to influence early growth and rank although it was earlier established that seed weight did not differ between groups. Due to its high correlation, analysis of covariance (ANCOVA) was undertaken, with seed weight used as the covariate. Although ANCOVA techniques were used for error control and adjustment of family means (Steel and Torie, 1960), they had no significant effect on the resulting mean square and F values. When variables are highly correlated, ANCOVA will not necessarily improve the calculation of error sums of squares. In addition, seed weights were only based on a maximum of 100 seeds. Consequently, the two-way ANOVA's described above were considered sufficient for these data. Sweet(1966, unpl.) found that in *P. radiata* heavy seeds produced seedlings with a higher number of cotyledons than did light seeds, and thereby concluded that a direct relationship existed between seed weight and initial seedling leaf area. Similarily, there was a correlation between black spruce seed weight and three- and four-month needle number in this experiment. Wilcox (1983) worked with 'big-seeded' and 'small-seeded' reciprocal crosses of 29 pairs of *P. radiata* and concluded that seed size can affect

initial differences in height growth, and result in unreliable family selection for height in both nursery and two-year field tests.

Within-family correlations were calculated for phenotype and rank order. Phenotypic correlations did not follow any specific trend (Appendix I); although like variables (i.e., three- and four-month height, or number of needles or laterals) tended to have positive and significant correlations, whereas unlike variables (i.e., height and the number of laterals) were not always positively or significantly correlated. This suggests that it may be possible to select individuals within families for like traits, but not for unlike ones.

Although the total phenotypic correlations (Table 22) were consistently significant and positive, within-family correlations were not. Within-family rank order correlations (Appendix I) were generally positive and often significant ($P<0.05$). Exceptions were families 7117 and 7146 that had some variables that were negatively correlated.

Rankings and Duncan's Multiple Range tests were undertaken on five- and six- month measurements, with treatments combined except for those variables where F x T interaction was significant (Tables 23 and 24).

Ranking the five- and six-month variables where the F x T interaction had not been significant followed the same trends as the three- and four-month measurements (and as in the field). Positive and statistically significant Spearman

Table 22. Simple correlations for three- and four-month greenhouse measurements#

	Three Month Height	Four Month Height	Three Month Laterals	Four Month Laterals	Three Month Needles	Four Month Needles	Family Seed Weight
Three Month Height	1.000	.862**	.661**	.608**	.872**	.7411*	.457**
Four Month Height	.862**	1.000	.591**	.656**	.844**	.8576**	.513**
Three Month Laterals	.661**	.591**	1.000	.758**	.716**	.657**	.484**
Four Month Laterals	.608**	.656**	.758**	1.000.	.708**	.705**	.487**
Three Month Needles	.872**	.844**	.716**	.708**	1.000	.859**	.515**
Four Month Needles	.740**	.857**	.657**	.705**	.859**	1.000	.601**
Family Seed Weight	.457**	.513**	.484**	.487**	.515**	.601**	1.000

Measurements recorded on all seedlings prior to treatment.

** P<.01

Table 23. Ranking and significance testing of variables measured at five and six months in the greenhouse *

Family	Variables							
	Five-Month Height	Five-Month Volume	Five-Month Diameter	Five-Month Laterals	Six-Month Height	Six-Month Diameter	Six-Month Branch Length	Six-Month Dormant Buds
	#							
7117	ab 3	ab 2	ab 2	a 1	a 4	a 2	ab 3	ab 5
7125	c 7	cd 7	c 7	bc 7	a 7	c 7	cd 7	ab 7
7128	bc 5	ab 4	ab 3	a 3	a 5	ab 4	bc 5	ab 6
7142	a 1	ab 3	abc 4	ab 6	a 2	ab 6	ab 2	a 1
7143	ab 2	a 1	a 1	a 2	a 1	a 1	a 1	ab 3
7146	abc 4	bc 5	abc 5	ab 5	a 3	ab 3	bc 6	ab 2
7150	c 6	bc 6	bc 6	ab 4	a 6	ab 5	bc 4	b 8
7153	d 8	de 8	d 8	cd 8	ab 8	cd 8	de 9	ab 4
7161	d 9	e 9	d 9	d 9	b 9	d 9	e 8	b 9

Families sharing common letters are not significantly different (P<.05)
* Family x Treatment interaction non-significant (P<.05)

Table 24. Ranking and significance testing for five- and six-month measurements where the F x T interaction term was significant (P<.05)

Family	Six-Month Laterals		Total Dry Weight		Shoot Dry Weight		Root Dry Weight		Six-Month Volume		Needle Dry Weight	
	Ntr*	Tr*	Ntr	Tr	Ntr	Tr	Ntr	Tr	Ntr	Tr	Ntr	Tr
7117	ab 4	a 1	a 1	ab 6	a 1	ab 5	a 1	a 1	a 1	a 2	ab 4	a 8
7125	c 7	a 7	c 7	b 7	c 7	b 7	c 7	b 8	b 7	b 8	a 1	a 6
7128	a 1	a 6	ab 3	ab 3	ab 3	ab 3	abc 3	a 2	ab 5	ab 4	a 2	a 4
7142	abc 5	a 5	abc 4	ab 2	ab 4	ab 2	bc 4	ab 4	ab 3	ab 5	ab 3	a 2
7143	ab 3	a 4	ab 2	a 1	a 2	a 1	ab 2	ab 5	a 2	a 1	ab 6	a 7
7146	bc 6	a 3	c 6	ab 4	bc 6	ab 4	bc 5	ab 3	ab 6	ab 3	ab 8	a 3
7150	ab 2	a 2	bc 5	ab 5	bc 5	ab 6	bc 6	ab 6	ab 4	ab 6	ab 7	a 5
7153	d 9	a 8	d 8	b 8	d 8	b 8	c 9	ab 7	bc 8	ab 7	ab 5	a 1
7161	d 8	b 9	d 9	b 9	d 9	b 9	c 8	b 9	c 9	b 9	c 9	a 9

*Tr = Treated seedlings
Ntr= Untreated seedlings
#Families with common letters are not significantly different (P<.05)

Rank Order correlations emphasize this trend. The selfs were always ranked at the bottom (as could be expected); family 7125 (the slowest of the 'fast' group) consistently ranked at the bottom of the 'fast' group. Significance testing indicated that of the variables recorded, the 'fast' and 'slow' groups could be easily differentiated at $P<0.05$ for only five-month height and diameter: otherwise the 'fast' growers could not be statistically separated from the 'slow' group.

For the six variables where the F x T interaction had been significant, ranking and significance testing were done on both $GA_{4/7}$-treated and control, untreated data (Table 24). Although there was variation in rank within the 'fast' group, the trend of all the 'fast' growers ranking at the top, and the 'slow' growers at the bottom persisted, regardless of treatment. Consequently, changes in relative rank of the families were not of any particular significance. In addition, rank order correlation coefficients of treated seedlings do not illustrate statistical changes from three-and four-month (control, untreated) measurements. Seed weight was not as highly correlated with the variables following GA application; many of the correlations appear to be lower, but still statistically significant.

It is interesting that for control, untreated seedlings some of the variables (six-month laterals, total and shoot dry weights) of the 'slow' growers could be statistically

separated from the 'fast' growers ($P<0.05$) once the GA was applied, the 'slow' growers were not statistically different from the 'fast' growers.

This result is important, as it suggests that the $GA_{4/7}$ exerted a moderate enhancement of growth on the 'slow' growers . Conversely, GA levels may not limit height growth in the 'fast', outcrossed families, as indicated by their insignificant response to exogenous GA application. Yet dry weight measurements increased for selfs, and decreased for all the fast growers, with the exception of total and shoot dry weights of family 7146 (Table 25). This suggests that $GA_{4/7}$ may have been supraoptimal to the 'fast' growers, as indicated by these dry weight measurements of $GA_{4/7}$-treated and control, untreated seedlings.

Phenotypic correlation coefficients computed across families for both $GA_{4/7}$-treated and control, untreated seedlings at five and six months were also positive, high and statistically significant (Tables 26 and 27), with the exception of correlations with rate of growth and the number of dormant buds variable (which are not particularily relevant, given that there were no significant differences among families for these variables). In addition, it is important that the phenotypic correlations are high and significantly correlated with three- and four-month measurements, regardless of treatment.

Within-family rank order correlations were predominantly not significant, suggesting that family rank

Table 25. Mean dry weight measurements of treated and untreated black spruce seedlings.

Family	Field Rank	Total Dry Weights		Shoot Dry Weights		Root Dry Weights	
		Untreated	GA 4/7 Treated	4/7 Untreated	GA 4/7 Treated	Untreated	GA 4/7 Treated
7117	6	1.1419	0.7137	0.3236	0.2147	0.2118	0.1136
7125	7	0.6672	0.5509	0.1795	0.1663	0.1016	0.0511
7128	3	0.9991	0.7565	0.2649	0.2173	0.1545	0.1016
7142	4	0.8675	0.7726	0.2648	0.2278	0.1426	0.0866
7143	2	1.0862	0.8801	0.3173	0.2666	0.1862	0.0803
7146	5	0.6935	0.7502	0.2049	0.2162	0.1338	0.0908
7150	1	0.8518	0.7404	0.2339	0.2061	0.1311	0.0693
7153	8	0.3023	0.5357	0.0837	0.1629	0.4444	0.0589
7161	9	0.2342	0.2551	0.0645	0.0875	0.0447	0.0302

Table 26. Phenotypic correlation coefficients for early growth measurements on untreated black spruce seedlings grown in the greenhouse

	HT1	HT2	HT3	HT4	VOL3	VOL4	D3	D4	L1	L2	L3	L4	N1	N2	DM4	BL4	TDW	SDW	NDW	RDW	WT
HT1	1.0000																				
HT2	.904**	1.000																			
HT3	.628**	.710**	1.000																		
HT4	.733**	.834**	.799**	1.000																	
VOL3	.665**	.706**	.757**	.700**	1.000																
VOL4	.687**	.763**	.699**	.771**	.829**	1.000															
D3	.568**	.629**	.684**	.624**	.921**	.731**	1.000														
D4	.613**	.701**	.634**	.730**	.711**	.927**	.712**	1.000													
L1	.712**	.697**	.493**	.556**	.680**	.694**	.604**	.643**	1.000												
L2	.625**	.678**	.344*	.530**	.608**	.679**	.622**	.676**	.785**	1.000											
L3	.410**	.498**	.497**	.427**	.709**	.664**	.750**	.663**	.631**	.748**	1.000										
L4	.478**	.603**	.418**	.512**	.606**	.698**	.638**	.724**	.653**	.809**	.821**	1.000									
N1	.871**	.869**	.620**	.728**	.712**	.772**	.624**	.723**	.795**	.714**	.547**	.608**	1.000								
N2	.760**	.870**	.686**	.777**	.735**	.776**	.676**	.755**	.749**	.716**	.576**	.675**	.900**	1.000							
DM4	.260	.202	.174	.3590*	.126	.127	.050	.124	.156	.075	-.230	-.229	.274*	.258	1.000						
BL4	.710**	.730**	.564**	.642**	.696**	.723**	.615**	.668**	.671**	.644**	.537**	.571**	.713**	.725**	.098	1.000					
TDW	.599**	.694**	.594**	.654**	.792**	.849**	.745**	.808**	.720**	.773**	.788**	.813**	.732**	.747**	-.048	.778**	1.000				
SDW	.704**	.777**	.673**	.748**	.851**	.925**	.757**	.835**	.741**	.749**	.722**	.746**	.782**	.786**	.062	.815**	.957**	1.000			
NDW	.176	.218	.307*	.373**	.354**	.395**	.413**	.489**	.124	.234	.329*	.266	.2076	.200	.094	.259	.489**	.426**	1.000		
RDW	.426**	.539**	.467**	.499**	.597**	.724**	.585**	.720**	.597**	.612**	.662**	.610**	.615**	.616**	-.031	.686**	.793**	.758**	.365**	1.000	
WT	.556**	.583**	.548**	.503**	.503**	.573**	.470**	.595**	.583**	.445**	.501**	.549**	.582**	.657**	-.052	.465**	.532**	.544**	.138	.443**	1.000

* - P<0.01 ** - P<0.001

HT1=3-Month Height
L1 =3-Month Number of Lateral Branches
N1 =3-Month Number of Needles
HT2=4-Month Height
L2 =4-Month Number of Lateral Branches
N2 =4-Month Number of Needles
HT3=5-Month Height
D3 =5-Month Diameter
L3 =5-Month Number of Lateral Branches
HT4=6-Month Height
D4 =6-Month Diameter
L4 =6-Month Number of Lateral Branches
DM4=6-Month Number of Buds
BL4=6-Month Length of Longest Lateral
TDW=6-Month Total Above-Ground Dry Weight
NDW=6-Month Needle Dry Weight
SDW=6-Month Stem and Branch Dry Weight
RDW=6-Month Rot Dry Weight
VOL3=5-Month Volume
VOL4=6-Month Volume
WT =family seed weight

Table 27. Phenotypic correlation coefficients for early growth measurements on treated black spruce seedlings in the greenhouse

	HT1	HT2	HT3	HT4	VOL3	VOL4	D3	D4	L1	L2	L3	L4	N1	N2	DN4	BL4	TDW	SDW	NDW	RDW	WT
HT1	1.000																				
HT2	.806**	1.000																			
HT3	.477**	.569**	1.000																		
HT4	.313*	.519**	.475**	1.000																	
VOL3	.417**	.488**	.709**	.334*	1.000																
VOL4	.368**	.498**	.422**	.719**	.550**	1.000															
D3	.363**	.429**	.586**	.252	.938**	.479**	1.000														
D4	.334*	.448**	.274*	.670**	.450**	.890**	.437**	1.000													
L1	.598**	.459**	.399**	.312*	.442**	.460**	.401**	.398**	1.000												
L2	.585**	.631**	.347*	.400**	.468**	.511**	.467*	.485**	.726**	1.000											
L3	.462**	.494**	.552**	.272*	.683**	.428**	.691**	.335*	.518**	.584**	1.000										
L4	.372**	.471**	.363**	.438**	.513**	.549**	.492**	.614**	.503**	.798**	.595**	1.000									
N1	.875**	.815**	.480**	.385**	.474**	.505**	.432**	.451**	.613**	.699**	.463**	.531**	1.000								
N2	.686**	.844**	.488**	.529**	.491**	.566**	.439**	.498**	.540**	.689**	.477**	.574**	.800**	1.000							
DN4	.291*	.283*	.243	.664**	.267	.543**	.210	.513**	.415**	.374**	.209	.250	.344*	.372**	1.000						
BL4	.389**	.520**	.483**	.589**	.572**	.614**	.542**	.585**	.557**	.567**	.472**	.549**	.432**	.505**	.338*	1.000					
TDW	.348*	.523**	.480**	.575**	.655**	.712**	.622**	.713**	.522**	.639**	.565**	.720**	.505**	.514**	.320*	.765**	1.000				
SDW	.381**	.584**	.551**	.682**	.691**	.777**	.625**	.732**	.545**	.646**	.584**	.701**	.517**	.572**	.419**	.797**	.961**	1.000			
NDW	.024	.055	.031	.274*	.273*	.394**	.290*	.561**	.179	.219	.143	.302*	.087	-.011	.324*	.321*	.549**	.465**	1.000		
RDW	.240	.356**	.390**	.452**	.561**	.663**	.527**	.648**	.441**	.454**	.437**	.524**	.383**	.364**	.332*	.546**	.742**	.752**	.379**	1.000	
WT	.345*	.435**	.168	.224	.268	.330*	.302*	.355**	.378**	.552**	.351*	.491**	.439**	.540**	.107	.468**	.436**	.414**	.071	.231	1.000

* - significant at P<0.01 ** - significant at P<0.001

HT1=3-Month Height
L1 =3-Month Number of Lateral Branches
N1 =3-Month Number of Needles
HT2=4-Month Height
L2 =4-Month Number of Lateral Branches
N2 =4-Month Number of Needles
HT3=5-Month Height
D3 =5-Month Diamter
L3 =5-Month Number of Lateral Branches
HT4=6-Month Height
D4 =6-Month Diameter
L4 =6-Month Number of Lateral Branches
DN4=6-Month Number of Buds
BL4=6-Month Length of Longest Lateral
TDW=6-Month Total Above-Ground Dry Weight
NDW=6-Month Needle Dry Weight
SDW=6-Month Stem and Branch Dry Weight
RDW=6-Month Rot Dry Weight
VOL3=5-Month Volume
VOL4=6-Month Volume
WT =family seed weight

depended on the variable measured (Appendix 1). In addition, the presence of several negative correlations indicated that rank order may even be inversely related for some early-growth variables.

Within-family phenotypic correlations were as inconsistent as the rank order correlations (Appendix 1). These results indicate the difficulty in early selection of individuals within families, yet strong positive among-family correlations suggest a possibility for early mass selection, as suggested by Squillace and Gansel (1974).

358-C-5-1

The seven families from this experiment were treated and analyzed as the nine families in Experiment 358-C-5-1. The results of the greenhouse experiment are only discussed briefly, primarily in comparison to the results of the previous experiment.

Family effect was significant for all but six-month height, six-month volume, and branch length at six-months. Treatment effect was significant for all variables but six-month branch length. Family x Treatment interaction was not-significant except for the number of dormant buds. These results are supported by the generally positive and statistically significant Spearman Rank Order correlations for $GA_{4/7}$-treated and control, untreated seedlings. Yet these correlations are not as high, and there are more exceptions than in experiment 358-C-1 families. Seed weight

was often poorly or negatively correlated with other variables; these results conflict with those in the previous experiment. Needle dry weight was again not very useful, since it was negatively and/or poorly correlated with early growth variables.

Simple correlations were not as consistent as those computed in the previous experiment. Although some correlations were statistically significant, there were many low, non-significant correlations among the variables, in addition to some negative correlations. Shoot dry weight and five-month volume were the most useful variables, since they were highly and positively correlated with all other variables but seed weight and the number of dormant buds.

Ranking of the seven families separated the 'fast' and the 'slow' groups, yet Duncan's Multiple Range tests could not statistically separate them. Consequently, there were no clearcut boundaries between the 'fast' and 'slow' groups. There are a number of problems that arise due to this inability to separate the groups. First of all, it would not be possible to statistically rogue/cull the 'slow' group based on any of the morphological characters measured on the seven families in Exp. 358-C-5-1. Second, this raises the question of whether the results of the first experiment were useful (in the context of rogueing) because two self-pollinated families (traditionally poor performers) had been used as the basis of a comparison with good growers.

C. Combined Data

From the individual study of both the greenhouse and field experiments (in Exp. 358-C-1), many of the variables recorded indicated high, positive and statistically significant phenotypic and rank order correlation coefficients for each family (within each separate experiment). The combination of family means into one data set allows us to consider the correlations of the very early growth (greenhouse) measurements with the four- to ten-year field measurements, thereby establishing the potential for juvenile-mature correlations in these families.

Phenotypic correlation coefficients for early growth and field variables (Table 28) are generally high, positive and statistically significant ($P<0.05$), with the exception of (greenhouse) needle dry weight. Thus, by eliminating needle dry weight (with a non-significant simple correlation) one could reliably attempt early mass selection on the remaining greenhouse variables and potentially obtain genetic gain in ten-year height. Yet in earlier analyses it was established that for only five-month height and diameter were the 'fast' and 'slow' groups statistically distinct. Consequently, the use of correlation coefficients alone as the basis for early selection may not be very reliable.

Like the phenotypic correlation coefficients, the Spearman Rank Order correlations (Table 29) were also predominantly high, positive and statistically significant. Again, six-month needle dry weight was the only exception.

Table 28. Simple correlations of means of field, greenhouse, and endogenous gibberellin measurements on black spruce.

	HB2	HB3	VOLB3	HT1	HT2	HT3	HT4	VOL3	VOL4	TDW	SDW	RDW	GA49G	GATG	GA49P	GATP	PTP	PTG
HB2	1.000																	
HB3	.998**	1.0000																
VOLB3	.928**	.927**	1.0000															
HT1	.601**	.597**	.549*	1.0000														
HT2	.685**	.695**	.673**	.942**	1.0000													
HT3	.707**	.700**	.657**	.799**	.908**	1.000												
HT4	.735**	.726**	.693**	.791**	.902**	.976**	1.000											
VOL3	.709**	.704**	.662**	.909**	.949**	.914**	.896**	1.000										
VOL4	.789**	.786**	.811**	.673**	.809**	.776**	.782**	.831**	1.000									
TDW	.808**	.806**	.830**	.709**	.811**	.737**	.741**	.794**	.930**	1.000								
SDW	.826**	.821**	.826**	.794**	.873**	.811**	.814**	.874**	.931**	.980**	1.000							
RDW	.788**	.784**	.794**	.627**	.711**	.642**	.643**	.718**	.852**	.949**	.939**	1.0000						
GA49G	.137	.161	.037	.429	.384	.273	-.016	.435	.062	.298	.416	.442	1.0000					
GATG	-.336	-.314	-.433	.112	.224	.183	.029	.395	.397	.230	.214	.113	.494	1.0000				
GA49P	-.556	.571	.374	.829	.803	.729	.507	.822	.504	.761	.844	.805	.802	.464	1.000			
GATP	.566	.582	.431	.803	.918*	.888*	.757	.970**	.856	.914*	.913*	.835	.490	.582**	.856	1.000		
PTP	.272	.306	.523	-.265	.033	.260	.387	.024	.254	-.047	-.020	-.084	-.178	-.314	-.177	-.072	1.000	
PTG	-.085	-.055	.189	-.591	-.386	-.199	-.100	-.394	-.222	-.480	-.426	-.438	-.131	-.396	-.407	-.468	.874*	1.000

* - significant at P<0.01 ** - significant at P<0.001

Table 29. Spearman Rank Order correlations For field, greenhouse and gibberellin measurements.

H83	.988**															
VOL83	.901**	.913**														
HT1	.476*	.429	.443													
HT2	.577**	.530*	.558*	.949**												
HT3	.542*	.495*	.532*	.886**	.933**											
HT4	.533*	.493*	.547*	.856**	.900**	.934**										
VOL3	.609**	.575*	.576*	.906**	.966**	.960**	.910**									
VOL4	.650**	.639**	.703**	.704**	.795**	.738**	.780**	.812**								
TDW	.713**	.707**	.779**	.631**	.720**	.617**	.634**	.732**	.918**							
SDW	.720**	.691**	.739**	.753**	.840**	.740**	.758**	.838**	.934**	.950**						
RDW	.783**	.772**	.786	.575*	.674**	.571*	.585*	.688**	.850**	.960**	.928**					
GA49G	.257	.257	-.143	.143	.143	-.029	-.200	.029	.029	-.086	.143	.143				
GATG	-.088	-.088	-.618	-.088	-.088	.000	.088	-.088	-.088	-.088	-.088	-.088	.382			
GA49P	.943*	.943*	.486	.829	.829	.943*	.886*	.886*	.886*	.771	.829	.829	.200	.000		
GATP	.986**	.986**	.551	.986**	.986**	.841	.754	.928*	.928*	.928*	.986**	.986**	.203	-.090	.899*	
PTP	-.086	-.086	.543	-.314	-.314	.257	.143	.143	.143	-.086	-.314	-.314	-.314	-.265	.029	-.203
PTG	-.371	-.371	.371	-.600	-.600	-.200	-.371	-.257	-.257	-.486	-.600	-.600	-.086	-.383	-.314	-.493	.829
	H82	H83	VOL83	HT1	HT2	HT3	HT4	VOL3	VOL4	TDW	SDW	RDW	GA49G	GATG	GA49P	GATP	PTP

H82 = nine-year height
H83 = ten-year height
Vol83= ten-year volume
HT1 = three-month height
HT2 = four-month height
HT3 = five-month height
HT4 = six-month height
VOL3 = five-month volume
VOL4 = six-month volume
TDW = total seedling dry weight
SDW = seedling dry weight
RDW = root dry weight
GA49G= Ga 4/9 per g seedling dry weight
GATG = Total Ga per g seedling dry weight
GA49P= Ga 4/9 per plant
GATP = Total Ga per plant
PTP = Total precursor per plant
PTG = Total precursor per g dry weight

Consequently, for the remainder of the field and greenhouse variables, rank order remained consistent (i.e., from three-month height to ten-year height and volume).

D. Analysis of Endogenous Gibberellin-like Substances

A number of GAs have been characterized from conifer tissues by definitive means (Pharis and Kuo, 1977), and the levels of endogenous GA-like substances in buds, shoots, and xylem sap positively correlated with shoot activity in several species (Ross *et al.*, 1983). Yet there appear to be no reports on endogenous GAs in black spruce, although GAs have been assessed in other *Picea* species.

Lorenzi (1975) investigated the factors controlling shoot growth in *Picea sitchensis* , in particular the seasonal changes in GA-like substances in needles and buds. Two GA-active fractions coinciding to a highly polar fraction and a fraction of lower polarity then GA_8 were detected in both needle and bud tissue. Lorenzi (1975) concluded that the less polar fraction represented the active GAs involved in growth and differentiation.

Dunberg (1976) found four regions of GA-like substances in three clones of *Picea abies*; these regions roughly coincided with gibberellins A_8, A_{20}, and A_1, plus a more polar fraction. Dunberg's results suggested that these GA-like substances were not only a 'prerequisite' for elongation growth in *P. abies*, but that GA hormone content in *P. abies* underwent rapid changes during the period from

bud burst to growth cessation. These results suggested that measurements of hormone contents at a single point in time may be inadequate for evaluating the possible role of hormone(s) over an extended period of vegetative growth (Dunberg, 1976).

In their review, Pharis and Kuo(1977) noted that there were higher concentrations of non-polar GAs in juvenile trees of *P. menziesii* Ross *et al.* (1983) indicated that fully elongated needles and shoots of *P. menziesii* (Mirb). Franco contained a relative abundances of more oxidized (polar) GA-like substances, but only limited quantities of less oxidized GA-like substances. This could imply a rapid rate of metabolism of the less polar GAs (Ross *et al.* 1983). The vegetative state is associated with a higher concentration of GA_3 and other GAs more polar than GA_3 (Pharis and Kuo, 1977).

Webber *et al.* (in press) concluded that endogenous and exogenous GAs in Douglas-fir families are used preferentially for vegetative growth processes first (with flowering occurring only when this demand has been satisfied). Thus not only is there variation in use of $GA_{4/7}$ by diffferent families of Douglas-fir, there is a suggestion that certain quantities or levels of GAs (endogenous and/or exogenous) may be required to promote vegetative growth, and that these levels may be correlated to family variation in morphological growth characters. Growth of black spruce seedlings may also be subject to similar family variation in

endogenous GAs.

Free GA-like substances in four principal regions eluted from C_{18}HPLC (fig. 2). The elution times of standard GAs are marked above the profiles. Precursor GA-like substances eluted in five principal regions from C_{18}HPLC (fig. 3).

Values of total GA-like activity (free GAs and precursors) for each cross were determined per plant and per gram tissue dry weight (Tables 30 and 31). Anomalous free GAs from the precursor fraction (the more polar $GA_{4/9}$-like substances and to the left of $GA_{4/9}$-like substances) were incorporated in Tables 32 and 33. On a per plant basis the results indicated a slight trend of higher levels of free GA-like activity in the fastest growing/ranking family (7143), with decreasing levels in the slower-growing families (7125, 7153). This relationship is most evident between $GA_{4/9}$-like substances, which represents the dominant peak of activity in all extracts. This trend is also evident (although to a lesser degree) per gram tissue dry weight.

Based on per gram tissue dry weight, the slower-growing families (7153,7125) had only a marginally lower concentration of total and $GA_{4/9}$-like activity. In fact, the relative rank of $GA_{4/9}$-like substances in family 7153 was second to replicate two of family 7143. However, family 7125 was significantly different from the fast growers (in both greenhouse and field tests) and not significantly different from the slow growers. As a result, the tendency for 7125

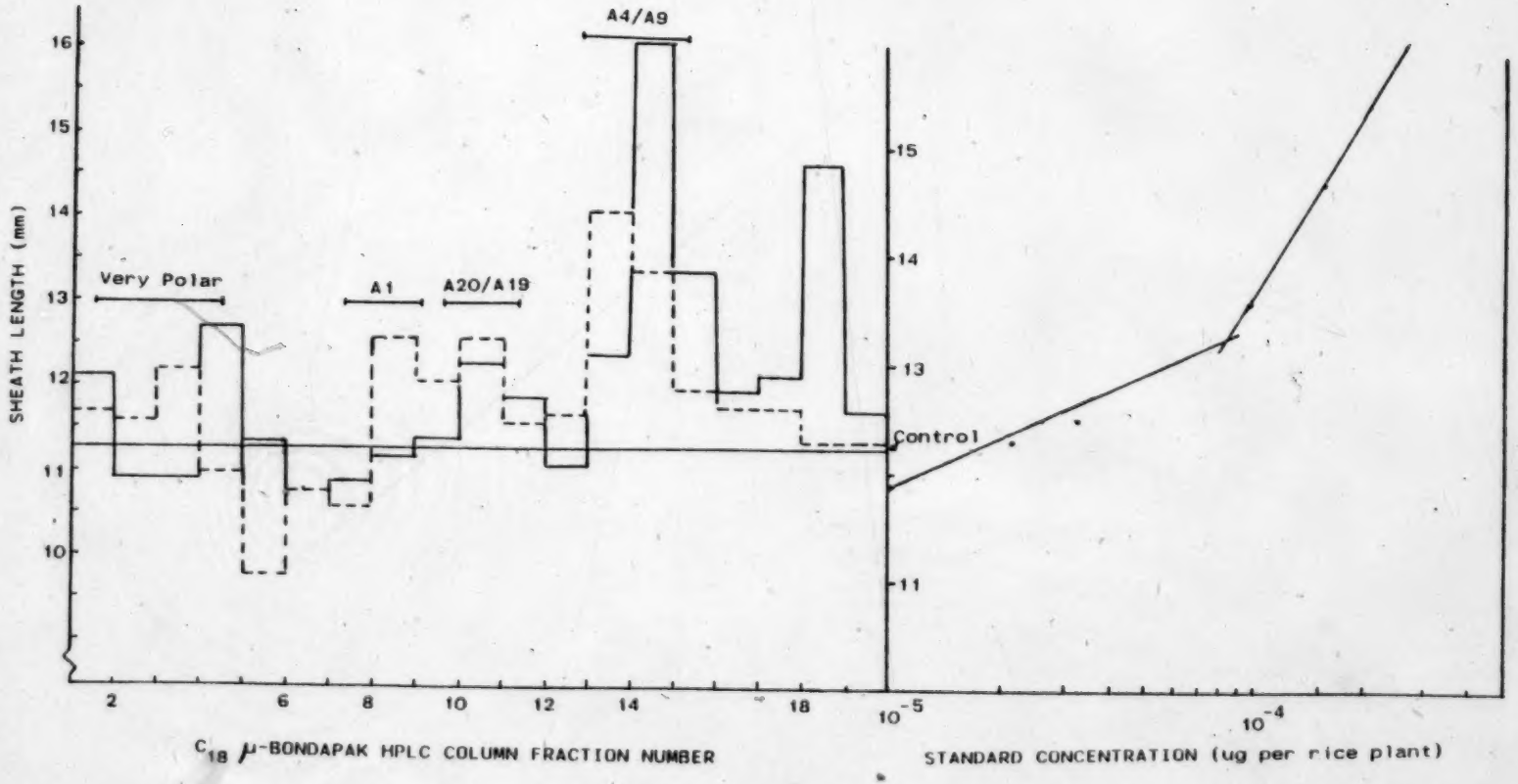

Fig 2 . Example of the Qualitative Spectrum of P. MARIANA Free Acids (1/200 dilution ----; 1/100 dilution —)

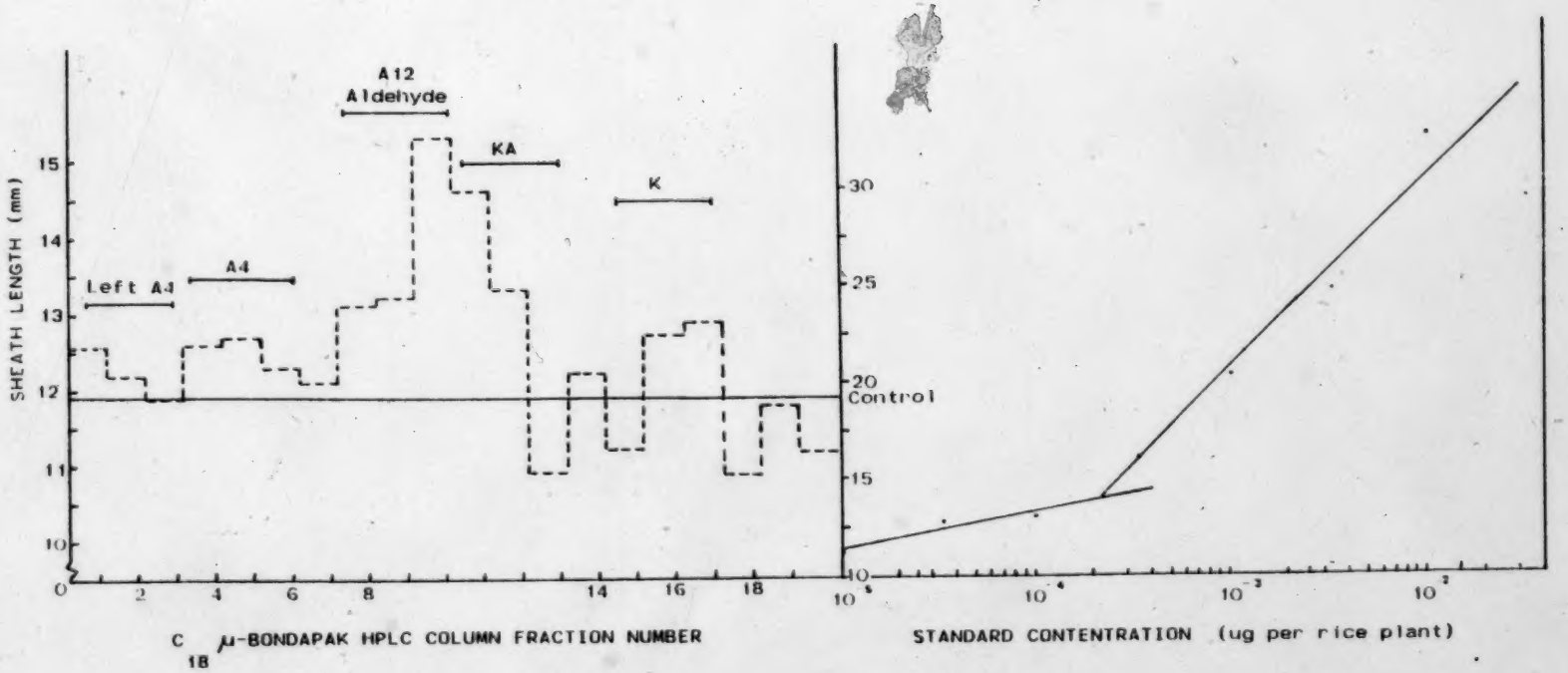

Fig 3 . Example of the qualitative spectrum of P. MARIANA precursors (1/50 dilution).

Table 30. Free gibberellin levels# (ng) in black spruce (P. mariana) per plant.

Family	Cross	Field Rank*	Greenhouse Stem Volume (5 mos)	Greenhouse Stem Volume (6 mos)	Stem Dry Weight	Number of Seedlings	ng/gm Tissue Dry Weight by Region: Very Polar	GA1-like	GA20/GA19 like	GA4/GA9 like	Mean of GA4/GA9 like	Mean of Total
1-7143	59x62	2	1	1	2	3	1.40	2.53	3.27	22.87		
											33.35	41.35
2-7143	59x62					3	0.73	5.60	2.47	43.83		
7146	63x62	5	5	3	6	3	1.98	----	1.27	14.13	14.13	17.38
1-7125	63x52	7	7	8	7	3	10.07	1.20	4.23	14.83		
											11.50	14.72
2-7125	63x52					3	0 .50	----	1.00	8.17		
7153	63x63 (selfed)	8	8	7	8	5	3 .22	0.44	0.40	8.16	8.16	12.22

*Comparison of height growth of nine families, nine years from outplanting

#Not including Anomalous Free GAs from Precursor Fraction

Table 31. Free GA levels# (ng) in black spruce (P. mariana) per gram tissue dry weight

Family	Cross	Field Rank*	Greenhouse Stem Volume (5 mos)	Greenhouse Stem Volume (6 mos)	Stem Dry Weight	Tissue Dry Weight	ng/gm Tissue Dry Weight by Region: Very Polar	GA1-like	GA20/GA19 like	GA4/GA9 like	Mean of GA4/GA9 like	Mean of Total
1-7143	59x62	2	1	1	2	3.72	1.13	2.04	2.64	18.44	27.33	33.90
2-7143	59x62	2				3.63	0.61	4.63	2.04	36.22		
7146	63x62	5	5	3	6	1.90	3.13	----	2.00	22.32	22.32	27.45
1-7125	63x52	7	7	8	7	2.08	14.52	1.73	6.11	21.39	15.70	27.77
2-7125	63x52	7	7	8	7	2.46	0 .61	----	1.22	9.96		
7153	63x63 (selfed)	8	8	7	8	1.77	9 .10	1.24	1.13	23.05	23.05	34.52

*Comparison of height growth of nine families, nine years from outplanting

#Not including Anomalous Free GAs from Precursor Fraction

Table 32. Free gibberellin levels# (ng) in black spruce (P. mariana) per plant

Family	Cross	Field Rank*	Greenhouse Stem Volume (5 mos)	Greenhouse Stem Volume (6 mos)	Stem Dry Weight	Number of Seedlings	ng/gm Tissue Dry Weight by Region				Mean of GA4/GA9 like	Mean of Total
							Very Polar	GA1-like	GA20/GA19	GA4/GA9		
1-7143	59x62	2	1	1	2	3	1.40	2.53	4.35	24.22	40.90	50.80
2-7143	59x62					3	0.73	5.60	5.17	57.53		
7146	63x62	5	5	3	6	3	1.98	----	2.55	19.36	19.36	23.89
1-7125	63x52	7	7	8	7	3	10.07	1.20	8.26	16.83	15.40	27.40
2-7125	63x52					3	0 .50	----	3.98	13.97		
7153	63x63 (selfed)	8	8	7	8	5	3 .22	0.44	2.04	9.04	9.04	14.74

*Comparison of height growth of nine families, nine years from outplanting

#Including Anomalous Free GAs from Precursor Fraction

Table 33. Free GA levels# (ng) in black spruce (P. mariana) per gram tissue dry weight

Family	Cross	Field Rank*	Greenhouse Stem Volume (5 mos)	Greenhouse Stem Volume (6 mos)	Stem Dry Weight	Tissue Dry Weight	ng/gm Tissue Dry Weight by Region: Very Polar	GA1-like	GA20/GA19	GA4/GA9	Mean of GA4/GA9 like	Mean of Total
like		like										
1-7143	59x62	2	1	1	2	3.72	1.13	2.04	3.51	19.53	33.50	41.63
2-7143	59x62	2				3.63	0.61	4.63	4.27	47.54		
7146	63x62	5	5	3	6	1.90	3.13	----	4.03	30.58	30.60	37.72
1-7125	63x52	7	7	8	7	2.08	14.52	1.73	11.93	24.27	20.60	37.72
2-7125	63x52	7	7	8	7	2.46	0 .61	----	4.86	17.03		
7153	63x63 (selfed)	8	8	7	8	1.77	9 .10	1.24	5.76	25.53	23.53	41.63

*Comparison of height growth of nine families, nine years from outplanting

#Including Anomalous Free GAs from Precursor Fraction

seedlings to be lower than 7146 and 7143 seedlings in GA-like substances may be important, despite limited differences in $GA_{4/9}$-like content as revealed in this study.

It is also important that family 7153 tended to contain similar levels of $GA_{4/9}$-like substances as family 7125 (i.e., 23.05μg vs 21.39μg), although much less than replicate two of family 7143 (with 36.22μg). In addition, $GA_{4/9}$-like levels (per gram dry weight of tissue) are positively correlated with nine- and ten-year field height and volume, and greenhouse height, volume and dry weight measurements (Tables 28 and 29), although none of the simple or rank order correlation coefficients are significant. Moreover, simple correlations between total GAs per plant are significant ($P<0.05$) for five-month volume, and total and shot dry weight measurements, indicating that the seedlings/families with largerr volume and mass (dry weight) also have inherently higher levels of GA-like substances.

These results complement evidence reviewed by Pharis and Kuo (1977) and Pharis(1976) which indicated that endogenous GAs are known not only to increase shoot elongation in many coniferous species, but that endogenous levels (in *Cupressus* species) are also positively correlated with shoot elongation.

Since the levels of each GA-like substance between replicates one and two of both family 7143 and 7125 vary widely, this suggests that the GA results should be regarded with some reservation. Even so, based on means, the trend

described above is apparent for the four families bioassayed for endogenous GAs. However, it is to be expected that larger seedlings (i.e., the fast-growers) which have more mass (stem and needles), would also have more GA per plant. There is some evidence of this in the tables of total GA and $GA_{4/9}$-like substances (per plant) (Tables 30 and 32). Family 7143 seedlings were the largest throughout the greenhouse study, and consequently had the largest quantities of GA-like substances per plant. Conversely, family 7153 seedlings were not only the smallest, but also contained the smallest quantities of GA-like substances per plant. For this reason, it may be more important to assess variation in GA levels on a per gram dry weight of tissue basis, instead of per plant.

Rood *et al.*(1983) showed that increased levels of GA-like substances were positively correlated with hybrid vigor in a comparison of maize inbreds and hybrid plants. In addition, Rood *et al.* (1983) suggested that GA levels may be involved in the regulation of hybrid vigor in maize.

Although the selfed black spruce family (7153) is consistently found to be the slowest grower in both the field and early growth experiments, it does not seem to be excessively GA deficient per unit of tissue. In fact, family 7153 has similar $GA_{4/9}$-like activity to families 7146 and 7125 (which share a common female parent). Nonetheless, 7153 does respond to exogenous $GA_{4/7}$ wereas 7143 does not.

Exogenous application of certain GAs is known to affect many growth processes (Pharis and Kuo, 1977), although exogenous application of $GA_{4/7}$ in this study did not greatly affect the overall ranking of the nine families. But it is important that the selfed families, plus family 7125, responded to the exogenous $GA_{4/7}$ application more than the higher-ranking families (i.e., 7143 and 7117); implying that exogenous $GA_{4/7}$ promoted height growth and may have been deficient in the selfs and family 7125 (Tables 34 and 35).

The $GA_{4/7}$ treatment effect was evident predominantly on dry weights (Table 25) and lateral branch measurements, and otherwise did not significantly affect height, diameter growth, or growth increment. Since the F x T interaction term was not significant, it was earlier concluded that $GA_{4/7}$ marginally enhanced the performance of the selfed families and some of the lower-ranking 'fast' growers. Although height growth was not significantly affected by $GA_{4/7}$ treatment, there were differences in height growth between lower-ranking families (including the selfs) and the higher-ranking families (Tables 34 and 35). The lower-ranking families increased in height growth possibly as a result of the $GA_{4/7}$ application more than the fast-growers, suggesting that endogenous GAs may not be significant (growth) limiting factors for outcrossed families.

Precursor levels were also determined per plant and per tissue gram dry weight (Tables 36 and 37). On a per gram dry

Table 34. Comparison of greenhouse height growth of nine untreated black spruce families at ages three- to six-months

Family			Age (Months)							
			3		4		5		6	
	Can For Serv Field Rating	Field Rank	Rank	Mean Ht (cm)	Rank	Mean Ht (cm)	Rank	Mean Ht (cm)	Rank	Mean Ht (cm)
7143	Fast	2	1	6.76	1	10.00	1	15.42	2	20.74
7142	Fast	4	2	6.46	2	9.62	2	15.42	1	21.09
7117	Fast	6	3	6.28	4	9.36	3	14.63	3	20.09
7128	Fast	3	4	6.08	3	9.41	4	13.91	4	18.86
7150	Fast	1	5	5.94	5	9.12	5	14.24	6	18.59
7146	Fast	5	6	5.63	6	8.38	6	13.63	5	18.61
7125	Fast	7	7	4.96	7	7.68	7	12.71	7	17.90
7161	Slow	9	8	4.07	8	5.93	8	8.68	9	11.73
7153	Slow	8	9	3.68	9	5.92	9	10.84	8	14.16

Table 35. Comparison of greenhouse height growth of nine treated black spruce families at ages three- to six-months

Family			Age (Months)							
			3		4		5		6	
	Can For Serv Field Rating	Field Rank	Rank	Mean Ht (cm)	Rank	Mean Ht (cm)	Rank	Mean Ht (cm)	Rank	Mean Ht (cm)
7143	Fast	2	2	6.36	1	9.87	2	15.59	2	20.04
7142	Fast	4	3	6.16	2	9.42	1	16.13	6	19.01
7117	Fast	6	1	6.40	3	9.32	3	15.57	1	20.10
7128	Fast	3	4	6.02	4	8.96	6	14.30	4	19.09
7150	Fast	1	7	5.24	7	8.66	7	13.09	7	18.54
7146	Fast	5	5	5.82	6	8.69	4	15.11	3	19.83
7125	Fast	7	6	5.40	5	8.73	5	14.53	5	19.01
7161	Slow	9	9	4.20	9	6.35	8	12.33	9	13.82
7153	Slow	8	8	4.54	8	7.68	9	11.98	8	17.86

Table 36. Precursor# levels (ng) in black spruce (P. mariana) per plant

Family	Cross	Field Rank*	Greenhouse Stem Volume (5 mos)	Greenhouse Stem Volume (6 mos)	Stem Dry Weight	Number of Seedlings	ng/gm Tissue Dry Weight by Region: A12 Aldehyde	Ka	K	Total	Mean
1-7143	59x62	2	1	1	2	3	7.12	5.75	1.18	14.05	8.62
2-7143	59x62					3	1.10	1.22	0.87	3.19	
7146	63x62	5	5	3	6	3	4.50	2.80	2.10	9.40	9.40
1-7125	63x52	7	7	8	7	3	10.33	8.82	1.45	20.60	12.32
2-7125	63x52	7	7	8	7	3	1.52	2.30	0.23	4.05	
7153	63x63	8	8	7	8	5	2.58	1.00	1.76	5.34	5.34

*Comparison of height growth of nine families, nine years from outplanting

#i.e. kaurene, kaurenoic acid, GA12 aldehyde-like

Table 37. Precursor# levels (ng) in black spruce (P. mariana) per gram tissue dry weight

Family	Cross	Field Rank*	Greenhouse Stem Volume (5 mos)	Greenhouse Stem Volume (6 mos)	Stem Dry Weight	Tissue Dry Weight	ng/gm Tissue Dry Weight by Region: A12 Aldehyde	Ka	K	Total	Mean
1-7143	59x62	2	1	1	2	3.72	5.74	4.64	0.95	11.33	6.98
2-7143	59x62					3.63	0.91	1.01	0.72	2.64	
7146	63x62	5	5	3	6	1.90	7.10	4.42	3.32	14.84	14.84
1-7125	63x52	7	7	8	7	2.08	14.90	12.72	2.09	29.71	17.32
2-7125	63x52					2.46	1.85	2.80	2.80	4.93	
7153	63x63	8	8	7	8	1.77	7.29	2.82	4.97	13.67	15.08

*Comparison of height growth of nine families, nine years from outplanting

#i.e. kaurene, kaurenoic acid, GA$_{12}$ aldehyde-like

weight basis family 7125 (low in free GA-like substances) had the most 'precursor' (i.e., eluted at HPLC Rts at or near GA_{12} aldehyde, kaurenoic acid, kaurene), with family 7143 (high in free GA-like substances) exhibiting low GA precursor-like activity. On a per plant basis (excluding selfs) precursor activity also supported this tendency, although less strongly. Yet again, the replicates taken of family 7143 and 7125 yielded quite divergent results. Because of this variation between the two replicates (possibly caused by analysis on different dates) the limited number of four controlled crosses of black spruce did not establish a definitive role or value of GAs in early growth and development in black spruce. However, the level of $GA_{4/9}$-like substances per gram tissue dry weight was correlated with rank order for the parameters of field height and greenhouse height and dry weights (Table 29).

Thus, based on this limited study it would not be possible to successfully select families using endogenous GA levels as the basis for a selection program. Certainly some trends in GA-like substances and precursor activity are evident; these trends need to be substantiated with replicated assays of endogenous GAs of more families.

IV. Conclusions and Recommendations

The results of the separate field and greenhouse experiments on nine controlled crosses of black spruce (Exp. 358-C-1) can be summarized as follows:

1. Family ranking/performance for height, diameter, and volume remained statistically unchanged from four to ten years from outplanting.
2. Based on field measurements, 'fast' and 'slow' growers are statistically distinct.
3. Family selection (for height) at four years from outplanting should be possible with black spruce. Selection of individuals within families should be considered with reservation, due to inconsistent results within each family and because some r^2 values decreased with age of measurement.
4. Monthly measurements of easily-assessed morphological characters at ages three to six months show highly significant family variation for total height, root collar diameter, lateral branch number, needle number, volume, branch length, total, shoot and root dry weight measurements. Not only do these black spruce families exhibit significant genetic variation, but the families should also respond to selection.
5. Weekly application of $GA_{4/7}$ beginning at 4.5 months influenced five- and six-month volume, six-month branch length, six-month bud formation, and all dry weight measurements. Height growth was not significantly

affected, although $GA_{4/7}$-treated 'slow' growers increased, on the average, in height growth at a faster rate than their control, untreated counterpart, and even faster than the $GA_{4/7}$-treated 'fast' growers.

6. Despite significant $GA_{4/7}$ treatment effect on the above measurements, the F x T interaction was only significant for six-month volume, lateral branch number, and dry weight measurements. Consequently, treatment only affected family rank order for those variables where F x T was significant.
7. Using Duncan's Multiple Range test it was determined at three and four months the 'fast' and 'slow' groups were statistically distinct for height, although the 'fast' growers were ranked above the 'slow' growers for all three- and four-month measurements. family 7125 (the slowest of the fast growers in the field and greenhouse) was not significantly different from the 'slow' group for lateral branch number and needle number.
8. At five and six months variables needed to be considered on the basis of F x T significance. Where F x T was non-significant, the relative rank order of the 'fast' and 'slow' groups always placed the slow families at the bottom, but after only five-months height and diameter were the groups statistically distinct. Where F x T was significant, the 'fast' group again was always ranked at the top, yet for only control, untreated six-month laterals and total and shoot dry weight were the 'fast'

and 'slow' groups statistically distinct.

9. Despite the lack of statistical differentiation among groups for greenhouse growth parameters, simple correlations and Spearman rank order correlations computed across the $GA_{4/7}$-treated and control, untreated seedlings indicated high, positive, statistical significance. Squillace and Gansel(1974) reported that high simple correlation coefficients indicate that less-than-mature trees can be selected for mature performance. These results on black spruce are consistent with those of Squillace and Gansel(1974), Lambeth(1980), Lambeth *et al.* (1983), and Waxler and van Buijtenen (1980).
10. Exogenous $Ga_{4/7}$ application did not influence/enhance family performance enough to alter rank order to any marked degree. Consequently, it would appear that a defecit in endogenous GA level was not the primary reason for the performance of the slower-growing families. Nontheless, slow growers responded to $GA_{4/7}$ in both height and shoot dry weight measurements, whereas the fast growers did not.
11. Simple correlations between the field and greenhouse means indicated that height and dry weight measurements in the greenhouse were highly correlated with height at four to ten years in the field.
12. In effect, the simple correlations and Duncan's Multiple Range test provide differing conclusions. On one hand

the simple correlations indicated that the early growth and field variables were highly correlated, and that family selection could be made. Spearman Rank Order correlation coefficients complement simple correlations. Conversly, the Duncan's Multiple Range test indicated that for most of these early growth variables, the families were not statistically distinct,and although the 'slow' growers were always ranked at the bottom, they are rarely statistically different from the 'fast' growers. Based on statistical differences, rogueing of the poorest growers would be impossible; yet if the bottom 18 percent were removed, as opposed to rogueing for statistical differences, then the uniform, positive, statistically significant phenotypic and rank order correlations would be a sufficient basis for family selection. As a result only the two 'slow' growers would have been removed on the basis of the greenhouse evaluation. Certainly, the normal process of selection on the basis of estimates of phenotypic correlations of provenance or family means (Franklin, 1979) allows early evaluation based on juvenile-mature correlations alone. The tree breeder needs to decide what criteria will be used to rogue/eliminate families/progeny/ provenances from further study.

This brings up the importance of sample size. Webb(1963) suggested that if a small number of progenies was being compared, a higher degree of accuracy was

required and mere statistical significance may not be strong enough. Although many previous studies have compared only ten or fewer families (with many of them open-pollinated), the results of this study with black spruce suggest that a larger sample should be included. Temperature-controlled greenhouses utilized during late spring to late summer should provide optimal conditions for growth, and should be ideal for work in early evaluations. Nanson (1970) indicated that with the possibility of a shorter generation interval, not only could more families or more individuals be tested, but also greater selection intensities and ultimately greater gains could be acheived. As well, a weaker juvenile-mature relationship can be successfully used in screening a larger number of progenies (Webb,1963).

13. Although there were differences in the endogenous GA activity/levels in the four families studied, the results are inconclusive, and are not significantly correlated with the field and early growth measurements, with the exception of total GA-like substances per plant and three- and four-month height, five-month volume, and total and shoot dry weight measurements. Trends of higher endogenous GAs in 'fast' growing families were suggested by the data; this hypothesis needs to be tested with additional GA bioassays. It is important, however, that varying levels of endogenous GAs can be identified at the family level, and that this variation

could possibly be correlated to variation in morphological characters and ultimately used as a selection tool.

Additional arguments that have not been addressed by this study are those relating to 'isolation' and 'crop' ideotypes. Cannell(1981) suggested that juvenile evaluation in progeny tests may favour juvenile 'isolation' ideotypes; this hypothesis could only be evaluated by correlating additional field measurements as the test enters crown closure and competition.

Competition between genotypes (Burdon, 1983) needs to be considered in relation to simple juvenile-mature correlations. Cannell(1981), suggested that judgement on family performance cannot be made accurately until several years after trees have come into competition with each other. In addition, height growth and many other traits expressed over a much longer period and will require continued scrutiny. Ultimately, if a family does not perform well for traits assessed at an early age, it consequently could be eliminated from further costly consideration.

This study indicates the potential for early selection of families in controlled crosses of black spruce where the study material is not very diversified. But additional families, particularily ones that are not self-pollinated, need to be included in future comparisons of 'fast' and 'slow' growing trees. Moreover, given the strong correlations between early greenhouse growth measurements

and field performance at ten years suggests that rogueing of the poorest performers as a result of greenhouse testing would provide rogueing information at least as reliable as that obtained from ten years of field assessment.

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V. Appendix I

Table 1. Descriptive measures of field variables recorded for each family in exp. 358-C-1

FAMILY:7117

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
Eight-year Height(cm)	21	190.00	380.00	309.29	53.488	-.789	-.354
Nine-year Height(cm)	21	225.00	440.00	356.57	61.015	-.788	-.453
Ten-year Height(cm)	21	280.00	485.00	403.33	60.173	-.877	-.005
Ten-year Diameter(cm)	21	3.5000	6.0000	5.4333	1.2678	-.178	-.878
Four-year Height(cm)	21	85.000	215.00	151.90	33.335	-.229	-.936
Six-year Height(cm)	21	135.00	280.00	221.19	42.245	-.638	-.671
Ten-year Volume	21	3185.0	30720.	15018.	7511.4	.213	-.798

FAMILY:7125

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
Eight-year Height(cm)	21	175.00	410.00	300.71	63.488	-.405	-.587
Nine-year Height(cm)	21	220.00	480.00	352.62	71.844	-.303	-.737
Ten-year Height(cm)	21	280.00	505.00	396.33	69.053	-.419	-.638
Ten-year Diameter(cm)	21	3.5000	8.5000	5.8810	1.3029	-.150	-.548
Four-year Height(cm)	21	75.000	185.00	130.24	27.408	-.178	-.387
Six-year Height(cm)	21	120.00	300.00	203.81	44.858	-.008	-.363
Ten-year Volume	21	3185.0	38485.	18342.	8402.5	.880	.062

FAMILY:7126

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
Eight-year Height(cm)	21	190.00	435.00	321.19	61.948	-.472	-.211
Nine-year Height(cm)	21	235.00	500.00	378.33	67.014	-.588	.180
Ten-year Height(cm)	21	270.00	585.00	433.57	86.687	-.425	.443
Ten-year Diameter(cm)	21	4.0000	7.5000	6.0476	.99681	-.518	-.629
Four-year Height(cm)	21	95.000	185.00	139.76	22.810	.015	-.142
Six-year Height(cm)	21	150.00	280.00	219.76	36.072	-.312	-.575
Ten-year Volume	21	5467.5	29813.	18837.	7036.7	.029	-.988

FAMILY:7142

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
Eight-year Height(cm)	21	180.00	435.00	314.76	60.795	-.225	-.153
Nine-year Height(cm)	21	240.00	495.00	373.57	61.383	-.312	-.185
Ten-year Height(cm)	21	300.00	530.00	416.43	58.718	-.174	-.849
Ten-year Diameter(cm)	21	4.0000	7.5000	5.9524	.99881	-.406	-.894
Four-year Height(cm)	21	90.000	260.00	144.05	35.583	1.070	1.515
Six-year Height(cm)	21	140.00	320.00	225.87	44.703	.076	-.350
Ten-year Volume	21	4800.0	28718.	15674.	6548.9	.090	-1.057

FAMILY:7143

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
Eight-year Height(cm)	21	255.00	445.00	332.62	51.588	.542	-.714
Nine-year Height(cm)	21	295.00	505.00	383.33	57.453	.446	-.734
Ten-year Height(cm)	21	350.00	580.00	430.24	60.158	.743	-.138
Ten-year Diameter(cm)	21	4.5000	8.0000	5.8867	1.0783	.481	-.701
Four-year Height(cm)	21	110.00	210.00	154.76	30.020	-.026	-1.207
Six-year Height(cm)	21	185.00	335.00	244.05	46.115	.117	-.783
Ten-year Volume	21	7067.5	32825.	14877.	7582.7	1.033	.285

FAMILY:7145

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
Eight-year Height(cm)	21	200.00	425.00	312.62	58.558	.080	-1.048
Nine-year Height(cm)	21	255.00	495.00	384.76	69.985	.238	-.920
Ten-year Height(cm)	21	300.00	575.00	412.62	77.278	.402	-.621
Ten-year Diameter(cm)	21	4.0000	8.0000	5.8429	1.1634	.157	-.979
Four-year Height(cm)	21	90.000	205.00	145.71	31.555	.330	-.765
Six-year Height(cm)	21	145.00	315.00	224.29	49.429	.060	-.823
Ten-year Volume	21	4980.0	34580.	14573.	8322.9	.740	-.258

FAMILY:7150

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
Eight-year Height(cm)	21	245.00	415.00	334.33	49.388	-.092	-.984
Nine-year Height(cm)	21	280.00	480.00	392.10	55.673	-.287	-.905
Ten-year Height(cm)	21	340.00	520.00	451.43	49.979	-.681	-.383
Ten-year Diameter(cm)	21	4.0000	7.5000	5.7476	.91467	.034	-.892
Four-year Height(cm)	21	95.000	195.00	145.71	26.822	.127	-.848
Six-year Height(cm)	21	145.00	290.00	227.48	39.857	-.214	-.592
Ten-year Volume	21	5820.0	28405.	15844.	6075.5	.277	-.772

FAMILY:7153

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
Eight-year Height(cm)	21	70.000	285.00	194.28	58.707	-.238	-.585
Nine-year Height(cm)	21	80.000	350.00	224.52	67.341	-.134	-.520
Ten-year Height(cm)	21	90.000	400.00	248.81	76.107	.018	-.479
Ten-year Diameter(cm)	21	1.0000	8.0000	3.6667	1.1547	.318	.004
Four-year Height(cm)	21	40.000	145.00	84.048	23.217	-.143	.300
Six-year Height(cm)	21	55.000	235.00	140.00	38.586	.187	.997
Ten-year Volume	21	90.000	14400.	4234.3	3410.0	1.284	1.783

FAMILY:7161

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
Eight-year Height(cm)	21	90.000	230.00	153.19	38.889	-.051	-.589
Nine-year Height(cm)	21	100.00	285.00	177.76	45.585	.213	.021
Ten-year Height(cm)	21	110.00	325.00	198.95	52.574	.378	.111
Ten-year Diameter(cm)	21	1.0000	5.0000	2.8000	.85688	.385	.404
Four-year Height(cm)	21	30.000	120.00	78.619	22.024	.021	.088
Six-year Height(cm)	21	55.000	180.00	116.19	31.855	.433	-.411
Ten-year Volume	21	110.00	8125.0	1776.4	1784.8	2.285	5.851

Table 3. Descriptive statistics for the untreated control greenhouse experiment*.

FAMILY:7117

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	5.5000	7.3000	6.2778	.55519	.483	-.837
L1	9	3.0000	6.0000	4.0000	1.0000	.795	-.188
N1	9	30.000	57.000	41.444	8.5458	.511	-.621
HT2	9	8.1000	10.800	9.3556	.94358	.387	-1.073
L2	9	7.0000	14.000	10.000	2.2361	.840	-.547
N2	9	70.000	137.00	98.333	20.031	.408	-.187
HT3	9	11.900	17.800	14.833	2.1471	.384	-1.298
D3	9	.12000	.19000	.15889	.19003 -1	-.529	-.523
L3	9	9.0000	24.000	17.778	4.8933	-.733	-.586
HT4	9	18.300	23.900	20.089	2.7511	.191	-1.323
D4	9	.14000	.24000	.21556	.30887 -1	-1.601	2.182
L4	9	13.000	30.000	23.778	5.1192	-.884	-.815
DM4	9	0.	12.000	5.8667	4.1633	-.718	-.875
BL4	9	7.8000	12.500	10.078	1.6300	.085	-1.143
TDW	9	.51810	1.5695	1.1419	.32515	-.593	-.487
NDW	9	.14200 -1	.28700 -1	.22411 -1	.42604 -2	-.881	-.488
SDW	9	.15490	.46800	.32387	.97683 -1	-.082	-.874
RDW	9	.31800 -1	.53380	.41183	.87325 -1	-.837	.238
VOLS	9	8337.3	26143.	17309.	7047.3	-.000	-1.563
VOLR	9	1877.1	9884.8	5774.8	2236.1	.073	-.038

FAMILY:7125

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	4.0000	5.2000	4.9556	.65729	-.485	-.527
L1	9	0.	4.0000	1.4444	1.2380	.758	.118
N1	9	12.000	25.000	20.000	5.3385	-.157	-.875
HT2	9	6.4000	8.8000	7.6778	.70848	-.100	-.330
L2	9	0.	8.0000	6.2222	2.3863	-2.258	3.553
N2	9	55.000	73.000	60.556	5.5703	1.310	.771
HT3	9	9.8000	14.600	12.711	1.5145	-.524	-.622
D3	9	.80000 -1	.15000	.13556	.22972 -1	-1.781	1.927
L3	9	0.	14.000	10.444	4.0981	-2.084	3.062
HT4	9	12.700	20.200	17.900	2.3516	-1.194	.633
D4	9	.14000	.20000	.17333	.20000 -1	-.884	-.375
L4	9	5.0000	22.000	16.778	5.0442	-1.481	1.434
DM4	9	0.	10.000	5.3333	3.0000	-.311	-.488
BL4	9	1.1000	9.4000	5.7000	2.3114	-.490	.222
TDW	9	.28080	.95320	.65717	.22291	-.648	-.647
NDW	9	.20100 -1	.38100 -1	.25287 -1	.50527 -2	1.180	.357
SDW	9	.73800 -1	.25270	.17949	.62743 -1	-.602	-.635
RDW	9	.35100 -1	.15280	.10184	.38850 -1	-.481	-.775
VOLS	9	4770.1	11883.	7833.7	2248.4	.415	-.727
VOLR	9	0.	3730.4	2588.2	1207.8	-1.480	.789

FAMILY:7126

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	4.6000	7.2000	6.0778	1.0968	-.278	-1.505
L1	9	2.0000	5.0000	3.6667	.86603	-.544	-.187
N1	9	18.000	42.000	33.000	8.3274	-.387	-1.520
HT2	9	8.3000	11.400	9.4111	1.5807	-.782	-.285
L2	9	7.0000	12.000	9.6667	1.8811	-.224	-.870
N2	9	38.000	100.00	68.778	19.974	-1.797	2.100
HT3	9	9.3000	15.800	13.811	2.2639	-.694	-.045
D3	9	.12000	.19000	.15000	.21213 -1	.187	-.083
L3	9	13.000	22.000	18.778	2.9488	.282	-.940
HT4	9	12.100	22.500	16.856	3.1985	-1.037	.182
D4	9	.17000	.22000	.20000	.18583 -1	-.349	-.805
L4	9	19.000	32.000	24.667	3.8730	.501	-.384
DM4	9	0.	14.000	5.6667	4.8477	.272	-1.004
BL4	9	4.3000	12.300	8.2333	2.3822	.031	-.864
TDW	9	.88150	1.3928	.99908	.28481	.688	-1.318
NDW	9	.20800 -1	.28300 -1	.24344 -1	.26740 -2	-.005	-1.409
SDW	9	.13410	.38850	.26483	.82388 -1	-.177	-.997
RDW	9	0.	.30230	.15456	.98011 -1	.042	-.988
VOLS	9	2580.0	21713.	14123.	8838.7	-.682	-.132
VOLR	9	1808.0	7153.3	4882.0	1837.8	-.187	-.815

FAMILY:7142

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	5.5000	7.7000	6.4556	.82327	.383	-1.462
L1	9	2.0000	6.0000	3.7778	1.3017	.429	-1.028
N1	9	22.000	50.000	35.444	8.9178	.024	-.901
HT2	9	8.7000	11.100	9.6222	.63633	.866	-.859
L2	9	7.0000	12.000	8.8889	1.8333	.430	-1.084
N2	9	78.000	148.00	94.556	20.409	1.866	2.359
HT3	9	12.900	18.200	15.422	1.8422	.156	-.708
D3	9	.90000 -1	.19000	.14556	.27437 -1	-.468	.436
L3	9	7.0000	23.000	12.889	5.3288	.740	-.649
HT4	9	17.800	25.400	21.089	2.4389	.824	-.693
D4	9	.18000	.23000	.19444	.18105 -1	.095	.940
L4	9	7.0000	30.000	19.556	8.7858	-.119	-.181
DM4	9	1.0000	24.000	10.111	7.1492	.880	-.248
BL4	9	7.4000	17.800	9.7333	3.2538	1.778	1.909
TDW	9	.63980	1.0630	.86750	.17918	-.570	-.885
NDW	9	.16300 -1	.30000 -1	.23088 -1	.42508 -2	.002	-.885
SDW	9	.17040	.34980	.26481	.82358 -1	-.058	-.253
RDW	9	.96300 -1	.19200	.14262	.33769 -1	.153	-1.303
VOLS	9	12841.	33874.	17982.	6520.2	1.724	1.858
VOLR	9	2267.1	7222.0	4369.8	1562.9	.610	-.373

FAMILY:7143

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	5.0000	8.5000	6.7556	1.1403	-.218	-.986
L1	9	3.0000	6.0000	4.7778	.97183	-.414	-.805
N1	9	25.000	50.000	42.444	7.6340	-1.357	1.088
HT2	9	7.9000	11.800	10.000	1.2258	.218	-.307
L2	9	7.0000	13.000	9.2222	2.0460	.610	-.787
N2	9	78.000	118.00	101.67	10.724	-.868	.888
HT3	9	13.700	17.600	15.422	1.2528	.234	-.857
D3	9	.14000	.20000	.16667	.24495 -1	.030	-1.651
L3	9	8.0000	25.000	16.222	5.1806	-.015	-.706
HT4	9	18.500	23.800	20.744	1.7472	.584	-.988
D4	9	.13000	.28000	.20778	.41468 -1	-.469	-.835
L4	9	16.000	31.000	23.889	4.4686	-.147	-.488
DM4	9	0.	18.000	7.4444	8.2071	.752	-.978
BL4	9	7.4000	14.100	10.688	2.1820	-.125	-.894
TDW	9	.55010	1.5870	1.0882	.33382	.038	-.746
NDW	9	.16500 -1	.28400 -1	.22100 -1	.49126 -2	.472	-1.238
SDW	9	.19320	.48360	.31726	.10071	.380	-.929
RDW	9	.85700 -1	.25030	.16622	.53988 -1	-.743	-.872
VOL5	9	12001.	28746.	18273.	4807.5	.140	-.744
VOL6	9	2838.2	10930.	5863.0	2571.0	.777	-.019

FAMILY:7146

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	4.8000	6.7000	5.8333	.81647	.190	-.835
L1	9	3.0000	4.0000	3.4444	.52705	.224	-1.950
N1	9	25.000	39.000	33.222	4.8577	-.480	-.660
HT2	9	7.0000	10.000	8.3778	1.0060	.133	-1.130
L2	9	8.0000	10.000	8.3333	1.6583	-.388	-1.401
N2	9	68.000	104.00	88.000	11.214	-.107	-.785
HT3	9	11.800	16.100	13.633	1.2338	.525	.073
D3	9	.12000	.18000	.14667	.11180 -1	-1.581	1.880
L3	9	8.0000	18.000	13.333	2.8284	-.324	-.073
HT4	9	18.200	21.100	18.611	1.5786	.148	-.928
D4	9	.17000	.21000	.19556	.13333 -1	-.797	-.443
L4	9	13.000	25.000	18.444	4.4190	.275	-1.402
DM4	9	2.0000	18.000	8.3333	5.8370	.023	-.581
BL4	9	5.8000	9.4000	8.7556	1.1425	1.370	1.338
TDW	9	.42330	1.0840	.89353	.20384	.822	-.287
NDW	9	.14800 -1	.23400 -1	.19811 -1	.26385 -2	-.858	-.047
SDW	9	.18048	.25270	.20492	.32582 -1	.249	-1.148
RDW	9	.98500 -1	.19770	.13378	.37242 -1	.554	-1.215
VOL5	9	7432.8	18278.	12897.	2805.4	-.648	-.773
VOL6	9	2103.1	5143.4	3638.7	966.12	.118	-.731

FAMILY:7150

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	4.5000	7.8000	5.9444	.88475	.852	.765
L1	9	2.0000	6.0000	3.6667	1.3229	.948	-.949
N1	9	22.000	46.000	31.667	7.8422	.837	.153
HT2	9	7.1000	12.000	8.1222	1.3208	.870	.989
L2	9	6.0000	15.000	8.2222	2.8674	1.211	.896
N2	9	83.000	112.00	93.000	8.9722	.978	.241
HT3	9	11.800	16.900	14.244	1.6846	.207	-.878
D3	9	.10000	.18000	.14111	.23588 -1	-1.217	-.321
L3	9	11.000	21.000	15.667	3.5742	.057	-1.301
HT4	9	17.200	21.300	18.589	1.4912	.848	-.781
D4	9	.18000	.24000	.20111	.24721 -1	-.134	-.815
L4	9	17.000	30.000	24.111	4.8610	.008	-1.510
DM4	9	0.	8.0000	3.4444	3.2068	.272	-1.277
BL4	9	5.2000	9.0000	6.9111	1.4166	.117	-1.524
TDW	9	.48380	1.0942	.85178	.20287	-.813	-.518
NDW	9	.18900 -1	.24300 -1	.21644 -1	.22979 -2	-.707	-.161
SDW	9	.14250	.32680	.23394	.58287 -1	-.162	-.820
RDW	9	.61000 -1	.18720	.13110	.30267 -1	-.373	-1.016
VOL5	9	8978.5	20403.	14877.	3890.8	-.052	-.882
VOL6	9	2614.3	5883.1	4248.3	1024.7	-.584	-.706

FAMILY:7153

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	5	2.8000	5.0000	3.6800	.88718	.707	-1.027
L1	5	0.	1.0000	.40000	.54772	.408	-1.833
N1	5	0.	20.000	11.400	8.1815	-.383	-1.711
HT2	5	3.7000	7.5000	5.5200	1.5172	-.447	-1.077
L2	5	0.	8.0000	3.0000	3.7417	.480	-1.591
N2	5	8.0000	71.000	40.600	25.106	-.305	-1.030
HT3	5	4.7000	13.000	10.640	3.5125	-1.348	.011
D3	5	.40000 -1	.13000	.88000 -1	.38341 -1	-.683	-1.042
L3	5	0.	13.000	5.8000	5.8566	-.157	-1.589
HT4	5	8.0000	17.400	14.180	4.8585	-1.380	.065
D4	5	.40000 -1	.18000	.13200	.85406 -1	-1.007	-.379
L4	5	0.	20.000	8.8000	8.5849	.775	-1.017
DM4	5	0.	12.000	6.4000	4.7749	-.138	-1.278
BL4	5	0.	4.6000	2.0400	2.0208	.437	-1.443
TDW	5	.46000 -1	.59580	.30228	.22122	.278	-1.384
NDW	5	.12800 -1	.28800 -1	.22180 -1	.58736 -2	-.722	-.457
SDW	5	.13000 -1	.15580	.83720 -1	.52916 -1	.084	-.853
RDW	5	.53000 -2	.84200 -1	.44380 -1	.33250 -1	.477	-.814
VOL5	5	86.703	8888.5	4813.2	3384.1	-.188	-1.035
VOL6	5	0.	3089.7	1403.8	1298.5	.069	-1.432

FAMILY:7161

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	6	3.2000	5.6000	4.0667	.93310	1.107	.146
L1	6	1.0000	4.0000	1.8667	1.2111	1.428	.387
N1	6	6.	37.000	12.500	12.942	1.237	.322
HT2	6	3.9000	8.3000	5.8333	1.4188	.367	-.108
L2	6	3.0000	11.000	5.6667	2.8048	1.287	.385
N2	6	11.000	80.000	39.500	22.572	.808	.105
HT3	6	3.9000	13.400	8.6833	3.5363	-.097	-1.254
D3	6	.30000 -1	.18000	.93333 -1	.47188 -1	-.041	-1.070
L3	6	1.0000	10.000	5.3333	3.0111	-.783	-.087
HT4	6	6.5000	17.700	11.733	4.3454	.075	-1.382
D4	6	.40000 -1	.17000	.85000 -1	.48477 -1	.462	-1.080
L4	6	4.0000	18.000	10.333	5.0067	.380	-.848
DM4	6	0.	16.000	6.1667	7.3868	.398	-1.583
BL4	6	1.8000	8.3000	4.0667	2.3001	1.077	.037
TDW	6	.88500 -1	.48700	.23420	.14788	.477	-1.074
NDW	6	.11900 -1	.18800 -1	.15283 -1	.27884 -2	.034	-1.520
SDW	6	.16300 -1	.14170	.84500 -1	.46389 -1	.657	-.780
RDW	6	.11600 -1	.91100 -1	.44883 -1	.30138 -1	.386	-1.059
VOLS	6	270.79	8356.3	2486.4	1917.2	.302	-1.221
VOLS	6	189.00	1017.8	512.43	386.65	.030	-1.838

FAMILY:7613

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	4.4000	7.0000	5.4333	.92186	.500	-1.162
L1	9	0.	5.0000	2.0000	1.5811	.402	-.390
N1	9	22.000	43.000	29.444	7.7639	.349	-1.138
HT2	9	7.1000	10.800	8.9444	1.5232	.056	-1.663
L2	9	2.0000	12.000	8.1111	2.9766	-.928	.123
N2	9	88.000	118.00	88.000	18.487	.427	-1.397
HT3	9	13.200	18.700	15.567	2.0100	.477	-1.184
D3	9	.10000	.18000	.13888	.22046 -1	.074	.168
L3	9	0.	23.000	10.888	8.3333	.259	-.170
HT4	9	17.800	25.100	21.156	2.7722	.391	-1.381
D4	9	.14000	.25000	.19000	.30822 -1	.326	.148
L4	9	0.	27.000	15.888	9.0200	-.486	-.917
DM4	9	8.0000	25.000	16.111	6.9182	-.382	-1.488
BL4	9	0.	12.000	5.8333	3.2943	.084	.208
TDW	9	.26220	1.3348	.60159	.29588	1.821	2.513
NDW	9	.13400 -1	.23700 -1	.17756 -1	.33588 -2	.215	-.732
SDW	9	.13190	.43220	.20612	.91486 -1	1.882	2.352
RDW	9	.46200 -1	.22640	.10258	.53528 -1	1.406	1.330
VOLS	9	8890.8	30495.	17692.	8137.8	.848	-.988
VOLS	9	0.	10487.	2750.9	2806.5	1.493	2.126

FAMILY:7618

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	5.0000	8.1000	6.7888	1.1163	.384	-1.227
L1	9	3.0000	6.0000	4.3333	.86603	.544	-.167
N1	9	20.000	53.000	38.667	11.543	-.549	-.843
HT2	9	7.1000	12.800	10.200	2.0493	-.289	-1.240
L2	9	8.0000	14.000	11.444	1.7401	-.581	-.024
N2	9	80.000	150.00	108.11	29.910	-.423	-.958
HT3	9	12.700	20.000	16.489	2.3342	-.093	-.950
D3	9	.14000	.20000	.16444	.20883 -1	.443	-.860
L3	9	14.000	26.000	19.556	4.1266	.563	-.784
HT4	9	17.400	26.800	22.367	3.0290	-.171	-1.058
D4	9	.15000	.23000	.19888	.28480 -1	-.505	-.843
L4	9	14.000	31.000	25.000	5.9582	-.850	-.247
DM4	9	0.	22.000	14.000	7.2111	-.850	-.518
BL4	9	4.7000	11.300	8.6667	2.2308	-.492	-1.008
TDW	9	.71810	1.7488	1.1730	.35803	.491	-1.077
NDW	9	.20800 -1	.28700 -1	.24688 -1	.17237 -2	-1.486	1.768
SDW	9	.22770	.81130	.38477	.87417 -1	.084	-.988
RDW	9	.83800 -1	.25020	.17578	.62300 -1	-.044	-1.261
VOLS	9	7588.8	47100.	24912.	12430.	.283	-.858
VOLS	9	4515.7	14441.	7918.9	3231.4	1.002	-.088

FAMILY:7637

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	4.4000	7.8000	6.2111	1.1537	-.484	-.834
L1	9	1.0000	4.0000	2.7778	.97183	-.414	-.805
N1	9	18.000	57.000	36.111	12.139	-.383	-.441
HT2	9	5.8000	11.500	9.2222	1.3862	-.241	.084
L2	9	6.0000	11.000	8.3333	1.8028	.015	-1.287
N2	9	63.000	150.00	95.111	25.429	.918	.332
HT3	9	10.800	18.100	14.633	2.2557	-.288	-.742
D3	9	.10000	.18000	.14111	.34440 -1	-.080	-1.330
L3	9	9.0000	18.000	13.000	3.7081	.811	-.788
HT4	9	15.400	25.800	20.378	3.2892	-.187	-.884
D4	9	.14000	.24000	.19444	.34681 -1	-.112	-1.241
L4	9	11.000	30.000	20.000	5.8820	.047	-1.382
DM4	9	0.	16.000	11.556	5.6814	-1.003	-.281
BL4	9	5.5000	11.300	8.4333	1.7081	-.015	-.498
TDW	9	.82450	1.2321	.80848	.22842	.545	-.840
NDW	9	.14400 -1	.23400 -1	.18344 -1	.25818 -2	-.432	-.077
SDW	9	.12250	.38900	.25733	.85005 -1	-.188	-1.276
RDW	9	.88300 -1	.18370	.12548	.50387 -1	.181	-1.701
VOLS	9	5875.7	38576.	17985.	9765.1	.838	.288
VOLS	9	2017.8	7218.9	4422.7	2017.2	.233	-1.449

FAMILY:7545

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	4.5000	6.7000	5.7444	.72130	-.218	-.883
L1	9	2.0000	4.0000	3.4444	.72648	-.837	-.503
N1	9	32.000	38.000	34.333	2.2361	.482	-1.267
HT2	9	7.8000	10.700	8.9000	1.0173	.886	-.795
L2	9	7.0000	11.000	8.8887	1.4142	.344	-1.172
N2	9	80.000	105.00	88.222	8.8261	.969	-.491
HT3	9	11.200	16.800	14.322	2.3053	-.639	-.278
D3	9	.70000 -1	.15000	.13444	.28034 -1	-1.826	2.447
L3	9	5.0000	20.000	14.111	5.7758	-.188	-1.583
HT4	9	18.800	24.300	19.878	2.5253	.849	-.710
D4	9	.14000	.21000	.18444	.20863 -1	-.995	.482
L4	9	10.000	31.000	21.333	8.3815	-.077	-1.492
DM4	9	4.0000	16.000	11.111	4.0787	-.437	-.979
BL4	9	6.2000	9.5000	8.0444	1.1958	-.288	-1.261
TDW	9	.46030	.89770	.71822	.18403	.082	-.787
NDW	9	.17100 -1	.21100 -1	.18744 -1	.13547 -2	.377	-.995
SDW	9	.13030	.31890	.22558	.55488 -1	-.055	-.400
RDW	9	.89000 -1	.19150	.13062	.38406 -1	.103	-.775
VOLS	9	8783.9	28300.	14787.	5719.2	1.510	1.831
VOLS	9	1377.3	9270.7	4622.1	2694.5	.552	-.928

FAMILY:7548

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	5.0000	7.5000	6.5556	.73843	-.959	.306
L1	9	0.	5.0000	2.1111	1.4530	.577	-.040
N1	9	14.000	47.000	37.000	9.8489	-1.515	1.390
HT2	9	7.1000	11.200	9.5000	1.0897	-.894	1.158
L2	9	3.0000	10.000	6.8887	2.5458	-.177	-1.213
N2	9	84.000	130.00	91.556	16.338	.745	.512
HT3	9	13.500	17.800	14.822	1.3103	1.506	1.502
D3	9	.80000 -1	.17000	.13222	.38976 -1	-.242	-1.495
L3	9	1.0000	14.000	7.7778	4.7639	.117	-1.343
HT4	9	18.300	24.800	20.467	1.9812	1.185	.804
D4	9	.15000	.21000	.17889	.20863 -1	-.107	-1.095
L4	9	5.0000	21.000	11.556	5.4109	.404	-.990
DM4	9	7.0000	19.000	13.889	3.9811	-.557	-.881
BL4	9	3.5000	8.6000	6.6444	2.0841	-.399	-1.430
TDW	9	.25240	1.0788	.91129	.29497	.322	-1.306
NDW	9	.14000 -1	.22300 -1	.18022 -1	.32570 -2	.174	-1.548
SDW	9	.11810	.38120	.20793	.81854 -1	.890	.218
RDW	9	.29800 -1	.24230	.10491	.88738 -1	.802	-.324
VOLS	9	9567.7	32898.	16365.	8748.1	1.898	2.018
VOLS	9	382.87	8813.8	3643.8	1992.7	.982	.084

FAMILY:7551

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	4.3000	6.4000	5.4222	.69802	-.323	-1.073
L1	9	1.0000	4.0000	2.7778	.97183	-.414	-.606
N1	9	14.000	39.000	28.556	9.8028	-.789	.770
HT2	9	6.2000	8.9000	8.7556	1.1270	-1.164	.847
L2	9	5.0000	8.0000	7.5556	1.2360	-.768	.119
N2	9	81.000	96.000	80.667	12.500	-.420	-1.283
HT3	9	12.200	17.800	14.844	1.7721	-.131	-1.127
D3	9	.13000	.17000	.14778	.13017 -1	.429	-1.038
L3	9	13.000	18.000	16.222	2.3333	-.784	-.600
HT4	9	17.400	22.700	20.187	1.8775	-.352	-1.038
D4	9	.13000	.23000	.18000	.30414 -1	-.284	-.492
L4	9	17.000	30.000	23.889	4.3718	.013	-.833
DM4	9	0.	11.000	4.8887	3.8408	.242	-1.148
BL4	9	4.9000	9.2000	7.4889	1.4181	-.885	-.736
TDW	9	.53370	1.2473	.85288	.23788	.226	-1.107
NDW	9	.18700 -1	.24400 -1	.20700 -1	.30858 -2	-.065	-1.583
SDW	9	.18050	.37110	.25001	.70538 -1	.438	-.878
RDW	9	.85100 -1	.14860	.10834	.27387 -1	-.247	-1.093
VOLS	9	7868.5	21877.	14885.	5157.7	-.120	-1.474
VOLS	9	2852.0	7281.0	5321.4	1859.1	-.407	-.884

FAMILY:7553

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
HT1	9	3.9000	5.1000	5.0333	.68695	.084	-.625
L1	9	2.0000	4.0000	3.3333	.70711	-.500	-.750
N1	9	21.000	43.000	30.556	8.6816	.114	-1.550
HT2	9	8.4000	9.3000	8.9667	.90277	-.495	-.626
L2	9	5.0000	11.000	8.1111	1.8333	-.043	-.736
N2	9	83.000	100.00	91.556	14.581	-.751	-.251
HT3	9	10.400	15.000	13.156	1.4808	-.558	-.638
D3	9	.12000	.20000	.16000	.25495 -1	.095	-.910
L3	9	5.0000	21.000	14.778	4.9186	-.787	-.238
HT4	9	15.400	21.700	18.256	2.0845	.013	-.928
D4	9	.18000	.25000	.20333	.28928 -1	.195	-.544
L4	9	14.000	31.000	24.778	5.1667	-.824	.155
DM4	9	0.	13.000	5.8889	4.3718	.070	-1.155
BL4	9	4.9000	10.200	7.8111	1.8120	-.455	-.441
TDW	9	.43100	1.3881	.91938	.29817	.087	-.782
NDW	9	.20300 -1	.34100 -1	.25700 -1	.38974 -2	1.041	.858
SDW	9	.11790	.38710	.24620	.82171 -1	.113	-.836
RDW	9	.57300 -1	.18880	.13038	.46948 -1	.134	-1.038
VOLS	9	4500.0	16982.	11529.	4026.8	-.309	-.882
VOLS	9	942.86	7782.8	4070.1	1947.4	.287	-.089

All 16 controlled crosses

where;

HT1=3-Month Height
L1 =3-Month Number of Lateral Branches
N1 =3-Month Number of Needles
HT2=4-Month Height
L2 =4-Month Number of Lateral Branches
N2 =4-Month Number of Needles
HT3=5-Month Height
D3 =5-Month Diamter
L3 =5-Month Number of Lateral Branches
HT4=6-Month Height
D4 =6-Month Diameter
L4 =6-Month Number of Lateral Branches
BM6=6-Month Number of Buds
BL6=6-Month Length of Longest Lateral
TDW=6-Month Total Above-Ground Dry Weight
NDW=6-Month Needle Dry Weight
SDW=6-Month Stem and Branch Dry Weight
RDW=6-Month Rot Dry Weight
Vol5=5-Month Volume
Vol6=6-Month Volume

Table 4. Within-family phenotypic correlations for three- and four-month early growth measurements.

FAMILY : 7117

	Three Month Height	Four Month Height	Three Month Laterals	Four Month Laterals	Three Month Needles	Four Month Needles
Three-Month Height	1.0000	.5708*	-.0848	.0441	.2908	.0412
Four-Month Height	.5708*	1.0000	-.2841	.1355	.4818	.5358
Three-Month Laterals	-.0848	-.2841	1.0000	.4089	.2187	-.0399
Four-Month Laterals	.0441	.1355	.4089	1.0000	.3573	.2848
Three-Month Needles	.2908	.4818	.2187	.3573	1.0000	.7873**
Four-Month Needles	.0412	.5358	-.0399	.2848	.7873**	1.0000

FAMILY: 7125

Three-Month Height	1.0000	.8080**	.2872	.1311	.8482**	.8019*
Four-Month Height	.8080**	1.0000	.4488	.3280	.7514**	.8891**
Three-Month Laterals	.2872	.4488	1.0000	.8197*	.2158	.5293
Four-Month Laterals	.1311	.3280	.8197*	1.0000	.2293	.4708
Three-Month Needles	.8482**	.7514**	.2158	.2293	1.0000	.8380*
Four-Month Needles	.8019*	.8891**	.5293	.4708	.8380*	1.0000

FAMILY: 7128

Three-Month Height	1.0000	.7387**	.3158	.1977	.7883**	.3884
Four-Month Height	.7387**	1.0000	.4479	.4243	.7888**	.7838**
Three-Month Laterals	.3158	.4479	1.0000	.8814**	.8884*	.8788*
Four-Month Laterals	.1977	.4243	.8814**	1.0000	.4384	.8700*
Three-Month Needles	.7883**	.7888**	.8884*	.4384	1.0000	.8822*
Four-Month Needles	.3884	.7838**	.8788*	.8700*	.8822*	1.0000

FAMILY: 7142

Height						
Four-Month Height	.8734*	1.0000	.3883	.0282	.8891*	.8432*
Three-Month Laterals	.4809	.3883	1.0000	.3284	.8342	.3481
Four-Month Laterals	-.0739	.0282	.3284	1.0000	.3788	.3158
Three-Month Needles	.7528**	.8891*	.8342	.3788	1.0000	.7872**
Four-Month Needles	.8348	.8432*	.3481	.3158	.7872**	1.0000

FAMILY: 7143

Three-Month Height	1.0000	.8878*	.4124	.2007	.7888**	.2748
Four-Month Height	.8878*	1.0000	.2118	.3284	.7874**	.4822
Three-Month Laterals	.4124	.2118	1.0000	.7412**	.4204	.2887
Four-Month Laterals	.2007	.3284	.7412**	1.0000	.3210	.3028
Three-Month Needles	.7888**	.7874**	.4204	.3210	1.0000	.8888*
Four-Month Needles	.2748	.4822	.2887	.3028	.8888*	1.0000

FAMILY: 7148

Three-Month Height	1.0000	.8863**	-.1475	.3574	.8113**	.3381
Four-Month Height	.8863**	1.0000	-.3388	.3598	.5710*	.7088**
Three-Month Laterals	-.1475	-.3388	1.0000	.3841	-.1934	-.2589
Four-Month Laterals	.3574	.3598	.3841	1.0000	.4471	.0845
Three-Month Needles	.8113**	.5710*	-.1934	.4471	1.0000	.3821
Four-Month Needles	.3381	.7088**	-.2589	.0845	.3821	1.0000

FAMILY: 7150

Three-Month Height	1.0000	.8868**	.5879*	.8183*	.8112**	.7542**
Four-Month Height	.8868**	1.0000	.4474	.8478*	.8727**	.7871**
Three-Month Laterals	.5879*	.4474	1.0000	.8778**	.4848	.3452
Four-Month Laterals	.8183*	.8478*	.8778**	1.0000	.8805**	.4954
Three-Month Needles	.8112**	.8727**	.4848	.8805**	1.0000	.8003**
Four-Month Needles	.7542**	.7871**	.3452	.4954	.8003**	1.0000

FAMILY: 7153

Three-Month Height	1.0000	.7888*	.7244*	.7852*	.8783**	.8121*
Four-Month Height	.7888*	1.0000	.3738	.8375	.8882**	.8838**
Three-Month Laterals	.7244*	.3738	1.0000	.8548	.8778	.4217
Four-Month Laterals	.7852*	.8375	.8548	1.0000	.7852*	.7513*
Three-Month Needles	.8783**	.8882**	.8778	.7852*	1.0000	.8153**
Four-Month Needles	.8121*	.8838**	.4217	.7513*	.8153**	1.0000

FAMILY: 7161

Three-Month Height	1.0000	.8348**	.8330**	.7578*	.8813**	.8183**
Four-Month Height	.8348**	1.0000	.7822*	.8738*	.8340**	.8852**
Three-Month Laterals	.8330**	.7822*	1.0000	.7824**	.8442**	.8772**
Four-Month Laterals	.7578*	.8738*	.7824**	1.0000	.7487*	.7744*
Three-Month Needles	.8813**	.8340**	.8442**	.7487*	1.0000	.8758**
Four-Month Needles	.8183**	.8852**	.8772**	.7744*	.8758**	1.0000

* - P<0.01 ** - P<0.01

Table 5. Spearman rank order correlation coefficients for early growth measurements at three- and four-months in the greenhouse

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FAMILY: 7117

Four-Month Height	.4717 N(18) SIG .024				
Three-Month Laterals	-.1285 N(18) SIG .306	-.3174 N(18) SIG .100			
Four-Month Laterals	-.0480 N(18) SIG .426	.0875 N(18) SIG .365	.2580 N(18) SIG .072		
Three-Month Needles	.3960 N(18) SIG .052	.4183 N(18) SIG .042	.2563 N(18) SIG .118	.2780 N(18) SIG .134	
Four-Month Needles	.0804 N(18) SIG .378	.5228 N(18) SIG .013	-.1243 N(18) SIG .312	.3639 N(18) SIG .127	.4553 N(18) SIG .029

FAMILY: 7126

Four-Month Height	.8084 N(18) SIG .000				
Three-Month Laterals	.3079 N(18) SIG .107	.3287 N(18) SIG .091			
Four-Month Laterals	.2851 N(18) SIG .153	.3788 N(18) SIG .060	.6188 N(18) SIG .003		
Three-Month Needles	.8059 N(18) SIG .000	.8803 N(18) SIG .000	.1808 N(18) SIG .238	.2568 N(18) SIG .152	
Four-Month Needles	.5819 N(18) SIG .006	.7453 N(18) SIG .000	.6408 N(18) SIG .002	.5337 N(18) SIG .002	.5172 N(18) SIG .003

FAMILY: 7128

Four-Month Height	.7318 N(18) SIG .000				
Three-Month Laterals	.3098 N(18) SIG .108	.5090 N(18) SIG .015			
Four-Month Laterals	.2058 N(18) SIG .207	.4228 N(18) SIG .040	.6524 N(18) SIG .000		
Three-Month Needles	.7795 N(18) SIG .000	.7737 N(18) SIG .000	.5738 N(18) SIG .008	.4079 N(18) SIG .048	
Four-Month Needles	.2935 N(18) SIG .119	.7481 N(18) SIG .000	.6368 N(18) SIG .003	.6819 N(18) SIG .001	.4894 N(18) SIG .029

FAMILY: 7142

Four-Month Height	.5771 N(18) SIG .006				
Three-Month Laterals	.4885 N(18) SIG .020	.3348 N(18) SIG .087			
Four-Month Laterals	-.0929 N(18) SIG .357	-.0742 N(18) SIG .385	.2477 N(18) SIG .161		
Three-Month Needles	.6823 N(18) SIG .001	.3681 N(18) SIG .068	.6883 N(18) SIG .007	.4228 N(18) SIG .040	
Four-Month Needles	.5823 N(18) SIG .006	.1049 N(18) SIG .339	.2484 N(18) SIG .160	.2879 N(18) SIG .123	.5923 N(18) SIG .005

FAMILY: 7143

Four-Month Height	.7147 N(18) SIG .000				
Three-Month Laterals	.5357 N(18) SIG .011	.3832 N(18) SIG .056			
Four-Month Laterals	.2883 N(18) SIG .116	.4889 N(18) SIG .020	.6918 N(18) SIG .001		
Three-Month Needles	.8000 N(18) SIG .000	.7170 N(18) SIG .000	.4401 N(18) SIG .034	.3148 N(18) SIG .102	
Four-Month Needles	.2621 N(18) SIG .147	.4295 N(18) SIG .038	.1898 N(18) SIG .226	.4362 N(18) SIG .034	.3834 N(18) SIG .058

FAMILY: 7148

Four-Month Height	.8873 N(18) SIG .001				
Three-Month Laterals	-.2844 N(18) SIG .145	-.3856 N(18) SIG .057			
Four-Month Laterals	.3343 N(18) SIG .088	.3858 N(18) SIG .071	.3781 N(18) SIG .080		
Three-Month Needles	.7287 N(18) SIG .000	.5380 N(18) SIG .011	-.2448 N(18) SIG .164	.4872 N(18) SIG .020	
Four-Month Needles	.3602 N(18) SIG .071	.7372 N(18) SIG .000	-.2850 N(18) SIG .144	.1404 N(18) SIG .288	.4058 N(18) SIG .047

FAMILY: 7150

Four-Month Height	.7947 N(18) SIG .000				
Three-Month Laterals	.5858 N(18) SIG .007	.3883 N(18) SIG .056			
Four-Month Laterals	.4587 N(18) SIG .028	.4968 N(18) SIG .018	.4585 N(18) SIG .028		
Three-Month Needles	.8560 N(18) SIG .000	.7845 N(18) SIG .000	.3985 N(18) SIG .052	.5406 N(18) SIG .002	
Four-Month Needles	.7158 N(18) SIG .000	.7945 N(18) SIG .000	.3452 N(18) SIG .080	.6298 N(18) SIG .003	.7953 N(18) SIG .000

FAMILY: 7153

Four-Month Height	.7888 N(10) SIG .005				
Three-Month Laterals	.6436 N(10) SIG .022	.2557 N(10) SIG .238			
Four-Month Laterals	.8536 N(10) SIG .001	.5350 N(10) SIG .056	.7898 N(10) SIG .003		
Three-Month Needles	.8308 N(10) SIG .001	.8301 N(10) SIG .000	.5084 N(10) SIG .066	.6560 N(10) SIG .018	
Four-Month Needles	.7754 N(10) SIG .004	.8848 N(10) SIG .000	.2988 N(10) SIG .203	.6897 N(10) SIG .033	.8085 N(10) SIG .000

FAMILY: 7181

Four-Month Height	.5085 N(12) SIG .001				
Three-Month Laterals	.5283 N(12) SIG .038	.5443 N(12) SIG .034			
Four-Month Laterals	.5158 N(12) SIG .018	.5185 N(12) SIG .042	.5548 N(12) SIG .010		
Three-Month Needles	.7480 N(12) SIG .003	.8885 N(12) SIG .000	.7498 N(12) SIG .002	.5834 N(12) SIG .027	
Four-Month Needles	.7055 N(12) SIG .008	.8805 N(12) SIG .000	.7858 N(12) SIG .001	.6080 N(12) SIG .018	.9344 N(12) SIG .000

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* - P<0.01 ** - P<0.001

Table 2. Within-family phenotypic correlations of nine field-grown black spruce controlled crosses from exp. 358-C-1.

FAMILY: 7117

	Four-Year Height	Six-Year Height	Nine-Year Height	Ten -Year Height	Ten-Year Diameter	Ten-Year Volume
Four-Year Height	1.0000	.8888**	.5888*	.5843*	.4795	.4630
Six-Year Height	.8859**	1.0000	.7189**	.7472**	.6285*	.6382**
Nine-Year Height	.5888*	.7189**	1.0000	.9734**	.8257**	.8388**
Ten -Year Height	.5843*	.7472**	.9734**	1.0000	.8141**	.8315**
Ten-Year Diameter	.4795	.6285*	.8257**	.8141**	1.0000	.9830**
Ten-Year Volume	.4630	.6382**	.8388**	.8315**	.9830**	1.0000

FAMILY: 7142

Four-Year Height	1.0000	.9088**	.7072**	.8529**	.6075*	.7052**
Six-Year Height	.9088**	1.0000	.8458**	.8210**	.7988**	.8423**
Nine-Year Height	.7072**	.8458**	1.0000	.9730**	.8892**	.9138**
Ten-Year Height	.8529**	.8210**	.9730**	1.0000	.8187**	.9038**
Ten-Year Diameter	.6075*	.7988**	.8892**	.8187**	1.0000	.9880**
Ten-Year Volume	.7052**	.8423**	.9138**	.9038**	.9880**	1.0000

FAMILY: 7143

Four-Year Height	1.0000	.8044**	.8338**	.8758**	.8184*	.8423**
Six-Year Height	.8044**	1.0000	.8887**	.7181**	.8877*	.8503**
Nine-Year Height	.8338**	.8887**	1.0000	.9882**	.7808**	.8385**
Ten-Year Height	.8758**	.7181**	.9882**	1.0000	.8008**	.8887**
Ten-Year Diameter	.8184*	.8877*	.7808**	.8008**	1.0000	.9897**
Ten-Year Volume	.8423**	.8503**	.8385**	.8887**	.9897**	1.0000

FAMILY: 7128

Four-Year Height	1.0000	.7883**	.8807*	.8503*	.5485*	.8454**
Six-Year Height	.7883**	1.0000	.8701**	.8207**	.8877**	.7958**
Nine-Year Height	.8807*	.8701**	1.0000	.8885**	.7888**	.8828**
Ten-Year Height	.8503*	.8207**	.8885**	1.0000	.7428**	.8747**
Ten-Year Height	.5485*	.8877**	.7888**	.7428**	1.0000	.8577**
Ten-Year Volume	.8454**	.7958**	.8828**	.8747**	.8577**	1.0000

FAMILY: 7146

Four-Year Height	1.0000	.9172**	.7881**	.7850**	.7530**	.7878**
Six-Year Height	.9172**	1.0000	.8878**	.8872**	.8822**	.8788**
Nine-Year Height	.7881**	.8878**	1.0000	.9838**	.9388**	.9842**
Ten-Year Height	.7850**	.8872**	.9838**	1.0000	.9174**	.9823**
Ten-Year Diameter	.7530**	.8822**	.9388**	.9174**	1.0000	.9730**
Ten-Year Volume	.7878**	.8788**	.9842**	.9823**	.9730**	1.0000

FAMILY: 7125

Four-Year Height	1.0000	.9529**	.8840**	.8547**	.8939**	.8834**
Six-Year Height	.9529**	1.0000	.7878**	.7483**	.7831**	.7807**
Nine-Year Height	.8840**	.7878**	1.0000	.9785**	.9369**	.9232**
Ten-Year Height	.8547**	.7483**	.9785**	1.0000	.9452**	.9287**
Ten-Year Diameter	.8939**	.7831**	.9369**	.9452**	1.0000	.9778**
Ten-Year Volume	.8834**	.7807**	.9232**	.9287**	.9778**	1.0000

FAMILY: 7150

Four-Year Height	1.0000	.9592**	.9167**	.8714**	.8075*	.8841**
Six-Year Height	.9592**	1.0000	.9513**	.9158**	.8704**	.7385**
Nine-Year Height	.9167**	.9513**	1.0000	.9722**	.7807**	.8241**
Ten-Year Height	.8714**	.9158**	.9722**	1.0000	.7553**	.8250**
Ten-Year Diameter	.8075*	.8704**	.7807**	.7553**	1.0000	.9843**
Ten-Year Volume	.8841**	.7385**	.8241**	.8250**	.9843**	1.0000

FAMILY: 7153

Four-Year Height	1.0000	.9288**	.7782**	.7930**	.7709**	.7370**
Six-Year Height	.9288**	1.0000	.8557**	.8713**	.8617**	.8497**
Nine-Year Height	.7782**	.8557**	1.0000	.9818**	.9720**	.9218**
Ten-Year Height	.7930**	.8713**	.9818**	1.0000	.9553**	.9355**
Ten-Year Diameter	.7709**	.8617**	.9720**	.9553**	1.0000	.9192**
Ten-Year Volume	.7370**	.8497**	.9218**	.9355**	.9192**	1.0000

FAMILY: 7161

Four-Year Height	1.0000	.9200**	.8018**	.7808**	.8307**	.7217**
Six-Year Height	.9200**	1.0000	.7934**	.7778**	.8574**	.7587**
Nine-Year Height	.8018**	.7934**	1.0000	.9753**	.9803**	.8877**
Ten-Year Height	.7808**	.7778**	.9753**	1.0000	.9714**	.9038**
Ten-Year Diameter	.8307**	.8574**	.9803**	.9714**	1.0000	.9154**
Ten-Year Volume	.7217**	.7587**	.8877**	.9038**	.9154**	1.0000